System Design Review for the Human Research Facility (HRF) MARES Rack

December 16th, 2003

Agenda

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- SRR RID Status
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- Verification Overview
- Integration Overview
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  - Electrical Design
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- Evaluations
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- Science and Operations
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  - Operations Nomenclature
  - Hardware Document
  - Procedures and Training
- Safety and Reliability
- Development Schedule
- Conclusions

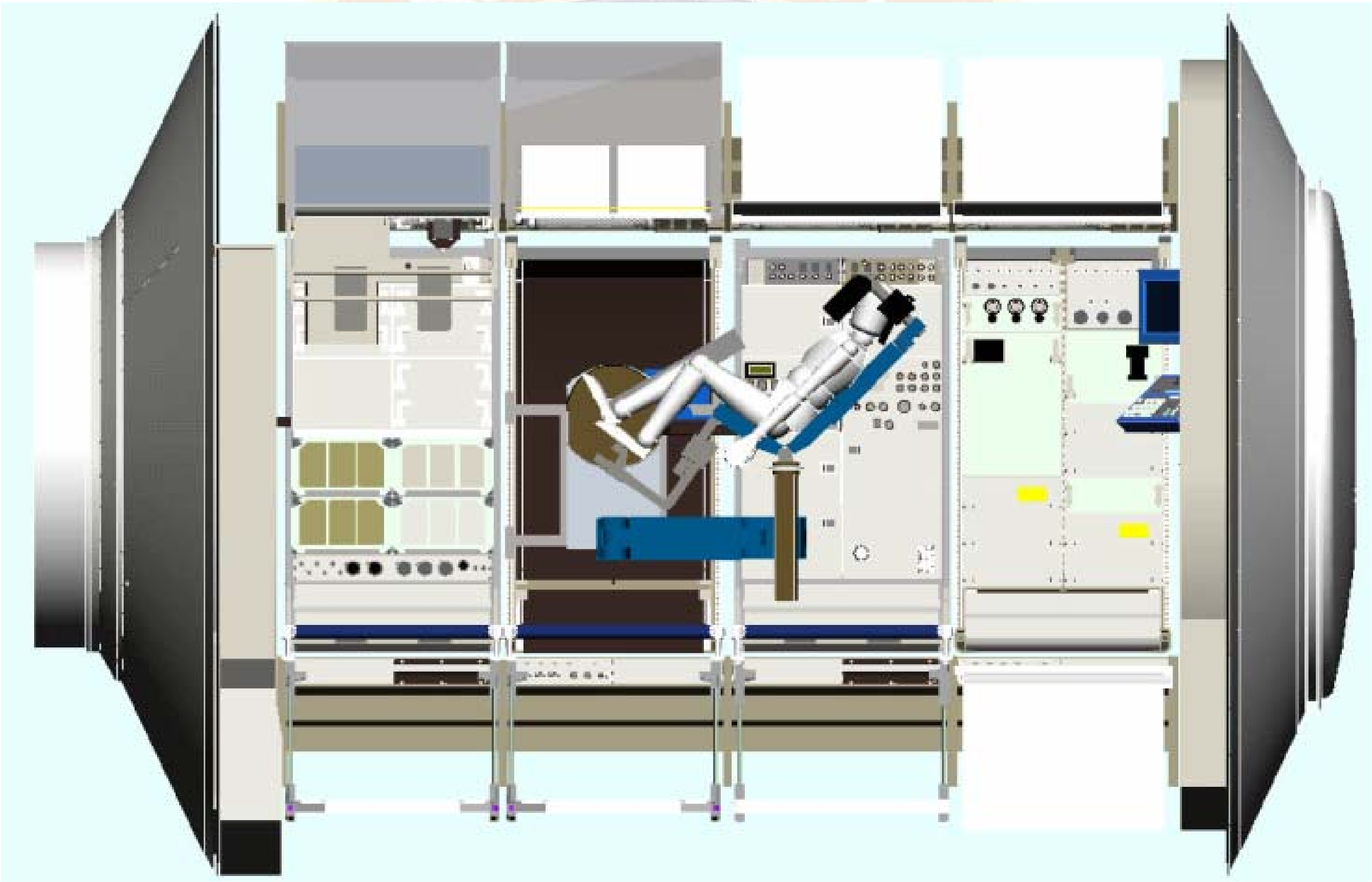
Review Board Members

- EB/J. Ratliff, Biomedical Systems Division (Chair)
- SM3/D. Baumann, MARES Experiment Systems Manager
- CB/L.D. Stevenson, Astronaut Office
- EA2/R. Schwarz, Project Management Office
- NT3/J. Stanford, GFE Branch, Flight Equipment Division

Team Members

EB Technical Monitor	**Liz Bauer**	Systems Engineering	**Jim Thompson** **Larry Walters**
SM Technical Monitor	**David Baumann**	Integration	**Elton Witt**
ESA MARES Manager	**Joaquim Castellsaguer**	Safety	**Nancy Wilson**
NTE MARES Manager	**Joan Mas**	Science and Operations	**Stuart Johnston**
LM Project Manager	**Clif Amberboy**	Stowage	**Dan Barineau**
International Liaison	**Yvonne Parsons**	Structural Analysis	**Lindy Kimmel** **Doan Van**
Project Engineering	**Joel Falcon** **Jake Fox** **Bobby Henneke**	Thermal Analysis	**Jerry Pantermuehl**
		Microgravity	**Michael Tseng**
Mechanical Engineering	**Jim Glasgow**	Materials	**Henry Kao**
Electrical Engineering	**Ron Bennett**	HFE	**Cynthia Hudy** **Danielle Paige**
Software	**Samme Lansdowne**	Reliability	**Dana Gomez** **Dan Butler**

Project Overview



Project Overview

- Develop Mech/Elect MARES Integration Hardware
- Receive Certified MARES from ESA
- Perform Integrated Verification Testing at JSC
- Deliver Integrated System to KSC
- Support MPLM Integration and UF-3 Launch (March 2006)
- Provide Operations Support for MARES Utilization

Quick Status

- System Requirements Review Conducted on 12/18/2002
- Received (2) International Standard Payload Racks in July 2003
- Developed, fabricated and evaluated prototype hardware
- Performed Analyses and adjusted the Design

SDR Process

➢Review Package available	12/08/2003
➢SDR Presentation	12/16/2003
➢Deadline for submitting RIDs	01/14/2004
➢RID Review	01/22/2004

Objective

- The SDR provides the detailed design data package and establishes the design baseline for fabrication and certification of the HRF MARES Rack.
- Compare the detail design against the baseline requirements to ensure all requirements are addressed.
- Receive Authorization to proceed to Flight Production and Certification Life Cycle Phase.
- Provide a status of the project issues and risks identified to date.

SDR Data Package

Data Item	Description	RIDable (Yes/No)
LS-71090-1A	Hardware Requirements Document for the Human Research Facility Muscle Atrophy Research and Exercise System (MARES) Rack (includes proposed changes, as outlined in the next document)	Yes
N/A - redlines	Changes to HRD from SRR	No
MARES-0000-SP-103-NTE	HRF Interface Specification - MARES & MARES Rack System	No
LS-71090-2	Software Requirements Specification (SRS) for the Human Research Facility Muscle Atrophy Research and Exercise System (MARES) Workstation Client Software	Yes
LS-71090-3	Software Test Plan for the Human Research Facility Muscle Atrophy Research and Exercise System (MARES) Workstation Client Software	Yes

SDR Data Package (Continued)

Data Item	Description	RIDable (Yes/No)
LS-71083D	HRF Software Design Document for the Human Research Facility Muscle Atrophy Research and Exercise System (MARES) Workstation Client Software	Yes
LMSEAT-34144	Structural Verification Plan for the Human Research Facility Muscle Atrophy Research and Exercise System (MARES) Rack and Payload Equipment	Yes
LS-71027-3	Phase II Flight Safety Data Package for the Human Research Facility	Yes
LS-XXXXX	Hardware Document for the Human Research Facility Muscle Atrophy Research and Exercise System (MARES) and MARES Rack	No
N/A - OZ MOU	MARES - SSP57000 Rev. E Applicability & Compliance Matrix	Yes

SDR Data Package (Concluded)

Data Item	Description	RIDable (Yes/No)
N/A - Procedure	HRF MARES Initial Deployment Procedures	No
MSAD-04-0022	PIP Thermal Analysis Report	Yes
N/A - Slides	HRF MARES Rack Preliminary Stress Analysis and Results	Yes
N/A - Op Nom	HRF MARES/MARES Rack Manifest and Operational Nomenclature	No
N/A - memo	HRF MARES Rack UIP/UOP Power Interface Board Derating Analysis Summary	No
N/A Drawings	HRF MARES Rack Drawings	Yes
N/A - form	Initial Assessment of Criticality (IAC)	No
N/A	SDR Presentation Slides – Will be available via the Internet address on December 10	No

System Requirements Review RID Status

- All 66 Review Item Discrepancies generated at the Systems Requirements Review have been closed
- The following Link will take you to the detailed RID status report: HRF MARES Rack SRR RID Status

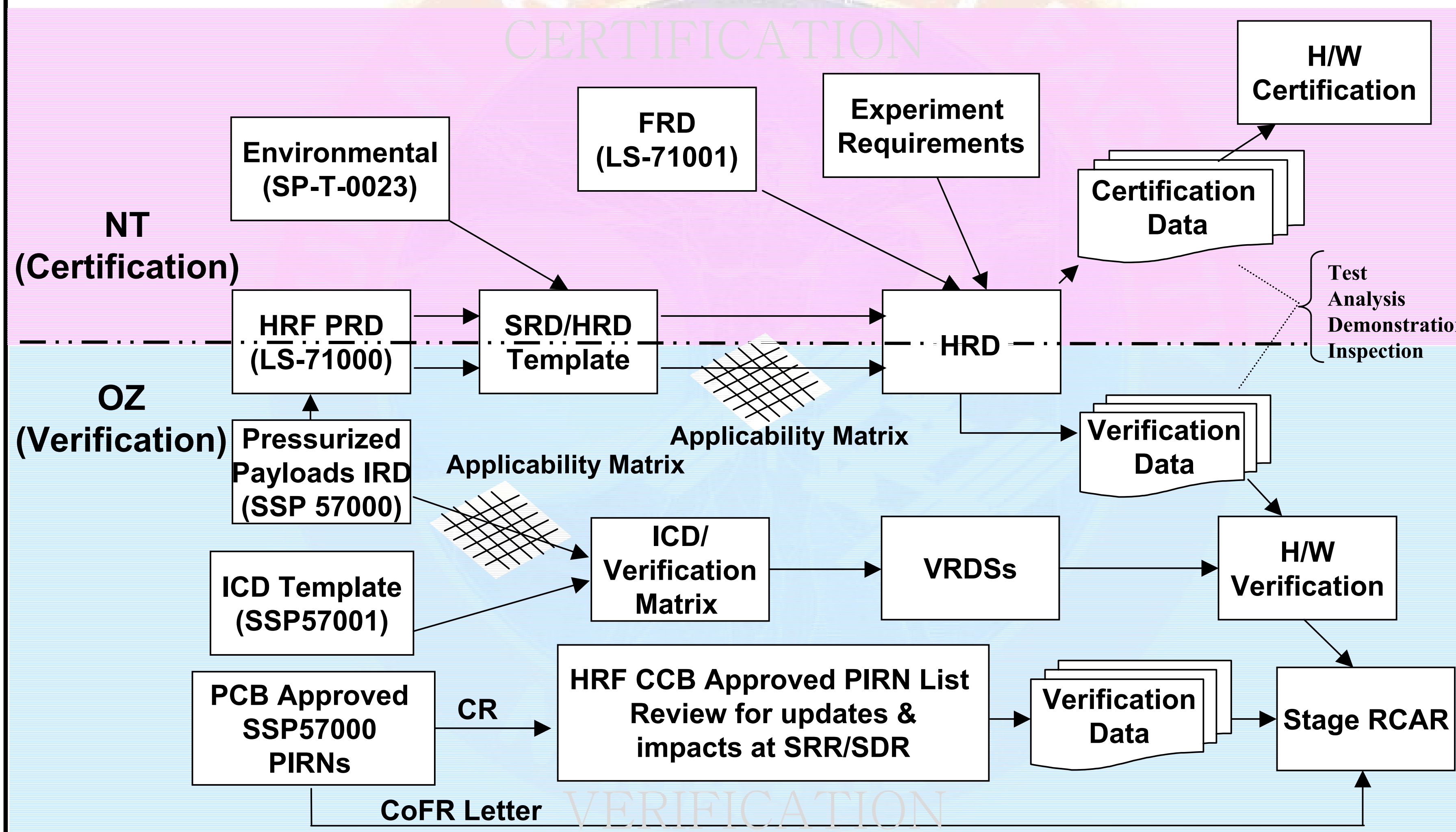
Requirements Overview

HRF MARES Rack System Design Review

Human Research Facility (HRF) Project

Larry Walters | 12/16/2003

Requirements Definition and Flow Down



LS-71090 Updates (Page 1 of 6)

LS-71090-1	Change Summary	Change Classification
Global	Replaces “71000A” with “71000” and replaces “57000E” with “57000”	Editorial or typographical
2.1	Replaces “LS-71000A” with “LS-71000B”	Editorial or typographical
2.1	Moves revision identification for NHB 6000.1 to the revision column and adds references to MIL-A-8625, NASA-STD-6001, NT-CWI-001, and SAIC-TN-9550	Editorial or typographical
2.1	Updates revisions for NSTS/ISS 13830, NSTS-1700.7, and NSTS-1700.7B ISS ADDENDUM	Requirement change – compliance already ensured by Payload Safety Review Panel
3.1.2.2	Deletes reference to maximum capacity for PIP	Editorial or typographical
3.1.3.3	Rewords first sentence to remove poor wording	Editorial or typographical
3.1.4.1 and 3.1.4.2	Adds figure references	Editorial or typographical
3.2.1.a,b,d	Deletes unnecessary functional requirements	Overlapping requirements deletion
3.2.2.2.2.1.2	Changes rationale for why the requirement is not applicable.	Non-requirement change

LS-71090 Updates (Page 2 of 6)

LS-71090-1	Change Summary	Change Classification
3.2.3.A	Deletes requirement for compliance with LS-71026, Human Research Facility (HRF) Reliability Plan For The HRF Integrated Rack	Relaxation of requirements – MARES has no safety critical interfaces except structural interface during launch.
3.2.5.1.4	Adds figure reference	Editorial or typographical
3.2.7.1.2.1.A, 3.2.7.1.2.3, and 3.2.7.1.2.3.C	Deletes repeated words	Editorial or typographical
3.2.7.2.10	Changes the paragraph references to be consistent with the paragraphs that are referenced by the SSP 57000 requirement	Editorial or typographical
3.2.7.2.12.1	Adds the load impedance requirements for 3 kW and 6kW interfaces	Requirements correction
3.2.7.9.3	Adds fire suppression note from template.	Non-requirement change
3.3.5.1 and 3.3.5.2.2	Deletes requirements concerning safety critical circuits	Requirements relaxation
3.3.6.39	Adds winghead fastener requirement	Requirements addition – winghead fasteners added to design
3.3.6.5.1.4 and subparagraphs	Adds handle requirements	Requirements addition – handles added to design

LS-71090 Updates (Page 3 of 6)

LS-71090-1	Change Summary	Change Classification
3.3.6.52.2.2	Adds extractor-type fuse holder requirement	Requirements addition – fuse holder added to design
3.3.8.1.4.B	Replaces verbiage with original SSP 57000 requirement verbiage (positive margins of safety rather than operation following exposure to)	Requirements relaxation
3.4.1	Replaces environmental operating temperature range with SSP 57000 documented range (61 to 86 degrees F reduced to 63 to 82 degreees F)	Requirements relaxation
3.4.2 and subparagraphs	Restores original template verbiage concerning vibration and sine sweep requirements while changing the verification method for sinusoidal resonance from test to analysis	Requirements addition – adds workmanship vibration and QAVT for the PIP only and sinusoidal resonance analysis
3.4.3	Clarifies functional acceptance test verbiage	Non-requirement change
3.4.4	Reduces EEE parts requirements to a burn-in	Requirements relaxation – Leaves parts control as documented for location of control and ensures parts survivability via burn-in
4.0 and 4.2	Deletes obsolete reference to Verification Data Sheets and deletes an unused functional performance verification paragraph	Non-requirement change

LS-71090 Updates (Page 4 of 6)

LS-71090-1	Change Summary	Change Classification
4.3.2 and subparagraphs	Restores original template verbiage concerning vibration and sine sweep verification methods while changing the verification method for sinusoidal resonance from test to analysis	Requirements addition – adds workmanship vibration and QAVT for the PIP only and sinusoidal resonance analysis
4.3.4	Reduces EEE parts requirements to a burn-in but adds power cycling to burn-in	Requirements change – relaxation of parts selection and control requirements but adds new power cycling requirement
4.3.10, 5.2.A, 5.3 and 5.4	Removes reference to reference document revision from places other than the applicable documents section	Non-requirement change
Appendix B	Deletes italicized text above table	Non-requirement change – italicized text is a note in the template
Appendix B	Changes VDS # column to Verification Method Column and adds reference to the ICD for the method	Non-requirement change
Appendix B	Adds HRF as the responsible provider of the verifications for Appendix B requirements	Non-requirement change
Appendix B	Makes Appendix B consistent with changes in HRD text	Non-requirement change

LS-71090 Updates (Page 5 of 6)

LS-71090-1	Change Summary	Change Classification
Appendix B	Documents minor changes to rationale for making Appendix B requirements not applicable	Non-requirement change
Appendix C	Deletes paragraph references with no shall statement	Non-requirement change
Appendix C	Deletes verification methods for requirements which are not applicable	Non-requirement change
Appendix C	Adds rationale for making 3.2.6.1 not applicable	Non-requirement change
Appendix C	Deletes italicized text at the bottom of the table	Non-requirement change – italicized text is a note in the template
Appendix C	Deletes comments for applicable requirements	Non-requirement change
Appendix C	Makes Appendix C consistent with changes to section 3.2.1 replaces requirements verbiage with requirement title in the requirement field	Non-requirement changes
Appendix C	Change verification methods to analysis for 3.2.1.1.C, 3.2.3.B, 3.2.3.C1, 3.2.3.C2, 3.2.3.C3, 3.2.3.C4, and 3.2.3.1	Verification method change
Table D-1	Makes table consistent with changes in HRD text	Non-requirement change

LS-71090 Updates (Page 6 of 6)

LS-71090-1	Change Summary	Change Classification
Table D-1	Adds note concerning HRF acceptance of risk for not performing workmanship vibe on the stowage drawers and the MARES rack	Exception to HRF requirements
Table D-2	Deletes example columns	Editorial or typographical
Table D-2	Adds columns for PIP, Cables Kits and Stowage Drawer	Requirements change
Table D-2	Makes table consistent with changes in HRD text	Non-requirement change
Table D-2	Deletes qualification thermal, bench handling and EMI/EMI control plan for the MARES Rack	Requirements relaxation
Table D-3	Deletes example columns	Editorial or typographical
Table D-3	Adds columns for PIP, Cables Kits and Stowage Drawer	Requirements change
Table D-3	Makes table consistent with changes in HRD text and Table D-1	Non-requirement change
Table D-3	Deletes acceptance thermal and burn-in for the MARES Rack	Requirements relaxation

APPLICABLE PIRNS

- List of applicable PIRNs is shown on next three pages
  - These PIRNS will be part of the RCAR process
  - Additional PIRNs will be added as they are approved by PCB

Applicable PIRNS (Page 1 of 3)

PIRN	SSP57000	IRD REQUIREMENT	APP	COMMENTS
57000NA0110H	3.1.2.1	QUASI–STEADY REQUIREMENTS	A	Microgravity Requirement (was TBD)
	3.1.2.2	VIBRATORY REQUIREMENTS	A	
	3.1.2.3.A	TRANSIENT REQUIREMENTS	A	
	3.1.2.3.B	TRANSIENT REQUIREMENTS	A	
57000NA0176H	3.2.2.5.1	REVERSE CURRENT LIMITS	A	Represents a complete overhaul of the requirements and is applicable to all modules (was TBD for JEM and APM)
	3.2.2.5.2	TRANSIENTS PARTIALLY CONTAINED WITHIN THE ENVELOPE	A	
57000NA0198A	3.2.2.3	COMPATIBILITY WITH SOFT START/STOP RPC	A	Updates JEM and APM specdification
57000NA0211B	3.12.8	COLOR	A	Table 3.12.3.4-1 modified requiring update to verification for 3.12.8 for rack only
57000NA0212D	3.1.2.6	ANGULAR MOMENTUM LIMITS	A	Adds angular momentum requirements (microgravity an update to the Generic Payload Microgravity Control Plan
	3.1.2.6.1	LIMIT DISTURBANCE INDUCED ISS ATTITUDE RATE	A	
	3.1.2.6.2	LIMIT DISTURBANCE INDUCED CMG MOMENTUM USAGE	A	

Applicable PIRNS (Page 2 of 3)

PIRN	SSP57000	IRD REQUIREMENT	APP	COMMENTS
57000NA0214	**3.12.6.4.1**	**HANDLES AND RESTRAINTS**	**A**	**Added because handles have been added to stowage drawers and the PIP**
57000NA0222	3.2.5.1.1	MATING/DEMATING OF POWERED CONNECTORS	A	Replaced letter MA3-97-093 with MA2-99-170 (NSTS 18798)
57000NA0223D	3.1.1.4	RACK REQUIREMENTS	A	Adds Rack Rotation while connected
57000NA0233D	3.2.2.12	MAXIMUM LOAD STEP SIZE	A	Adds 3kW step change limit per SSP 52051
57000NA0235A	**3.2.5.2**	**RACK MAINTENANCE SWITCH (RAAK POWER SWITCH)**	**A**	**Adds switch directionality and labeling requirements**
57000NA0238A	3.2.1.3.1	TRANSIENT VOLTAGE – INTERFACE B	A	Updates for APM voltage transient limits
	3.2.1.3.2	TRANSIENT VOLTAGE – INTERFACE C	A	
57000NA0240G	3.12.7	IDENTIFICATION LABELING	A	Update to Payload Labeling Requirements

PIRNS bolded were added since MARES Rack SRR

Applicable PIRNS (Page 3 of 3)

PIRN	SSP57000	IRD REQUIREMENT	APP	COMMENTS
57000NA0246A	3.2.2.1.G	UIP AND UOP CONNECTORS AND PIN ASSIGNMENTS	A	Adds SSP 57001 reference for SUP
	3.2.2.1.H	UIP AND UOP CONNECTORS AND PIN ASSIGNMENTS	A	
	3.2.2.1.I	UIP AND UOP CONNECTORS AND PIN ASSIGNMENTS	A	
57000NA0254B	**3.2.5.4**	**GROUND FAULT CURRENT INTERRUPTERS (GFCI)/PORTABLE EQUIPMENT DC SOURCING VOLTAGE**	**A**	**Deletes requirement**
	3.2.5.5	**PORTABLE EQUIPMENT/POWER CORDS**	**A**	**Adds redundant ground path for voltages over 30 VDC**
	3.12.9.1	**ELECTRICAL HAZARDS**	**A**	**Deletes requirement**
57000NA0258A	3.1.1.4.N	RACK REQUIREMENTS	A	Adds keep-out zone for KBAR
57000NA0269B	**3.2.2.7.1**	**INTERFACE B**	**A**	**Updates load impedance limits**
57000NA0274A	**3.1.1.1**	**GSE INTERFACES**	**A**	**Adds RID keepout envelope**
	3.1.1.4	**RACK REQUIREMENTS**	**A**	**Changes inspection from umbilical drawings to payload drawings**

PIRNS bolded were added since MARES Rack SRR

Waivers and Deviations

Exceptions (Page 1 of 2)

SSP 57000 Rev. E	Requirement Title	Exception	Status
3.1.1.3.D	Loads Requirements – Crew Induced Loads (125 lbf over a 4 in. x 4 in. area)	Mounting of the MARES Linear Adapter cannot take the specified kick load.	The rationale for exception is that MARES will be crew-tended. HLPF-053-1-0001-001 grants approval from the HRFCCB to seek exception but the exception is still TBD.
3.1.1.7.A 3.1.1.7.B 3.1.1.7.2.B 3.1.1.7.3.A	On-Orbit Payload Protrusions – Lateral Extension Beyond Rack Edge, On-Orbit Payload Protrusions – Coverage of Seat Track, On-Orbit Semi-Permanent Protrusions – Envelope, and On-Orbit Temporary Protrusions - Envelope	MARES will extend across both adjacent racks, cover some seat track, extends beyond the semi-permanent envelope when stowed, and extends beyond temporary envelope when deployed	Envelope performance of the MARES stowed/deployed design cannot be significantly improved. MARES is willing to schedule around neighboring activities. MARES semi-permanent protrusions can be removed within 10 minutes. Exception is still TBD because of envelope definition and design changes but will not affect integration or ISS topology.

Exceptions (Page 2 of 2)

SSP 57000 Rev. E	Requirement Title	Exception	Status
3.12.4.4.2	Mounting Bolt/Fastener Spacing	Tool sweep clearances are not met for the LSP bolts	Tool extenders from the ISS tool kit will be used Exception is still TBD.
3.12.6	Restraints and Mobility Aids	Extra restraints are needed in the MARES Rack interior	Extra restraints will be provided by HRF. Exception is still TBD.

Verification Plan

Certification/Verification Approach

MARES Verification Requirements History

- Memorandum of Understanding (MOU) baselined 06/06/2002
- MARES project evolved into a system which includes a rack and power interface
- MOU update in progress to add requirements which became applicable because of the addition of the rack
- Exception for protrusions in work

Verification Methods Overview

- Verification Methods are in the MOU which will become ICD (SSP 57245)
- Closure of the requirements in SSP 57245 are the responsibility of HRF and will be closed primarily with HRD verification closure data from ESA/NTE

Verification Requirements Summary

- SSP 57000E / SSP 57245 Requirements
  - 208 Applicable Requirements out of 503
    - 94 Mechanical (ME & HFE)
    - 65 Electrical (EL)
    - 17 Structural (ST)
    - 11 Command and Data Handling (CD)
    - 12 Safety
    - 6 Environmental (EN)
    - 2 Materials and Process (MP)
    - 1 Fire Detection (FD)

Integration Overview

Integration: Phases

L-24	L-18	L-12	L-7
Planning	Ground Processing	Testing	Pre-launch
• Logistics and Ground Support Equipment (GSE) • Facility Prep • Ground Processing, Integration, and Test Plans • TRR Prep	• Logistics • Fit Checks, Mating • Mechanical Integration • Software Integration • Configuration Management • Procedure Development	• Component Cert. Tests to HRD • Verif. Tests to ICD/IRD • Science Verif. Test • Profile and Procedure Validation	• Pack and Ship • KSC Offline • KSC Online • CEIT/Bench Review • Launch Prep • MPLM Install

Integration: Planning

- Logistics and Ground Support Equipment (GSE)
  - MARES Racks and GSE will be located in 241 clean room and 100J
  - MARES units and GSE will be located in 241, J36, and TBD (BDC)
  - GSE: 1-G chair floor stand (NTE); 1-G Main Box stand (NTE)
- Facility Preparations
  - J241 room 100J was modified to accommodate hardware and personnel
- Detailed Planning
  - Detailed integration plans for MARES Rack logistics are completed
  - Plans for MARES logistics and integrated testing are in work
- Facility Test Readiness Review (TRR)
  - Project / Facility Readiness Review held June 11, 2003
  - Hazard Analysis for Launch Integration Facility will be required
  - TRR planned to be held prior to first MARES units being delivered

Integration: Ground Processing

- **Logistics**
  - MARES Racks located in 241; MARES units pending delivery
- **Fit Checks and Mates**
  - Fit checks with Mockup completed; other checks pending delivery
- **Mechanical Integration**
  - MARES Rack and MARES typically will <u>not</u> be integrated
  - GSE will be used to support the main box for testing activities
- **Software Integration**
  - Will develop procedure to functional-test all software interfaces
  - Components: MARES software and HRF-developed software
- **Configuration Management**
  - Will maintain records of h/w and s/w configurations for traceability

Integration: Ground Processing, Continued

- **Procedure Development**
  - **Lift Plan**
    - **Include lift plan details in hardware handling documents (below)**
  - **Hardware Setup and Functional Test**
    - **Develop LS document for MARES Rack and MARES handling, functional test, and packing for shipment**
  - **Science Verification Test**
    - **Develop with Ops and performed on TPS**
  - **KSC Off-line Test**
    - **Should be same as functional test; if not will write TPS**
  - **KSC On-line Test**
    - **Adapt Functional Test and Develop with KSC to include into TAP**

Integration: Testing

- **Component (MARES Rack) Certification to HRD**
  - Supported by I&T personnel, if required
  - Some HRD requirement tests utilize integrated configuration
- **Verification (Integrated Configuration) to ICD/IRD**
  - Support to Verification Sponsors
  - Some Verification test data will support Certification and vice versa
- **Science Verification Test (SVT)**
  - Demonstration of science capability and data capture for review
- **Profile Tests and Procedure Validation**
  - Performance data for Operations (Power draws,etc.)
  - Procedure dry-runs for Ops and future activities

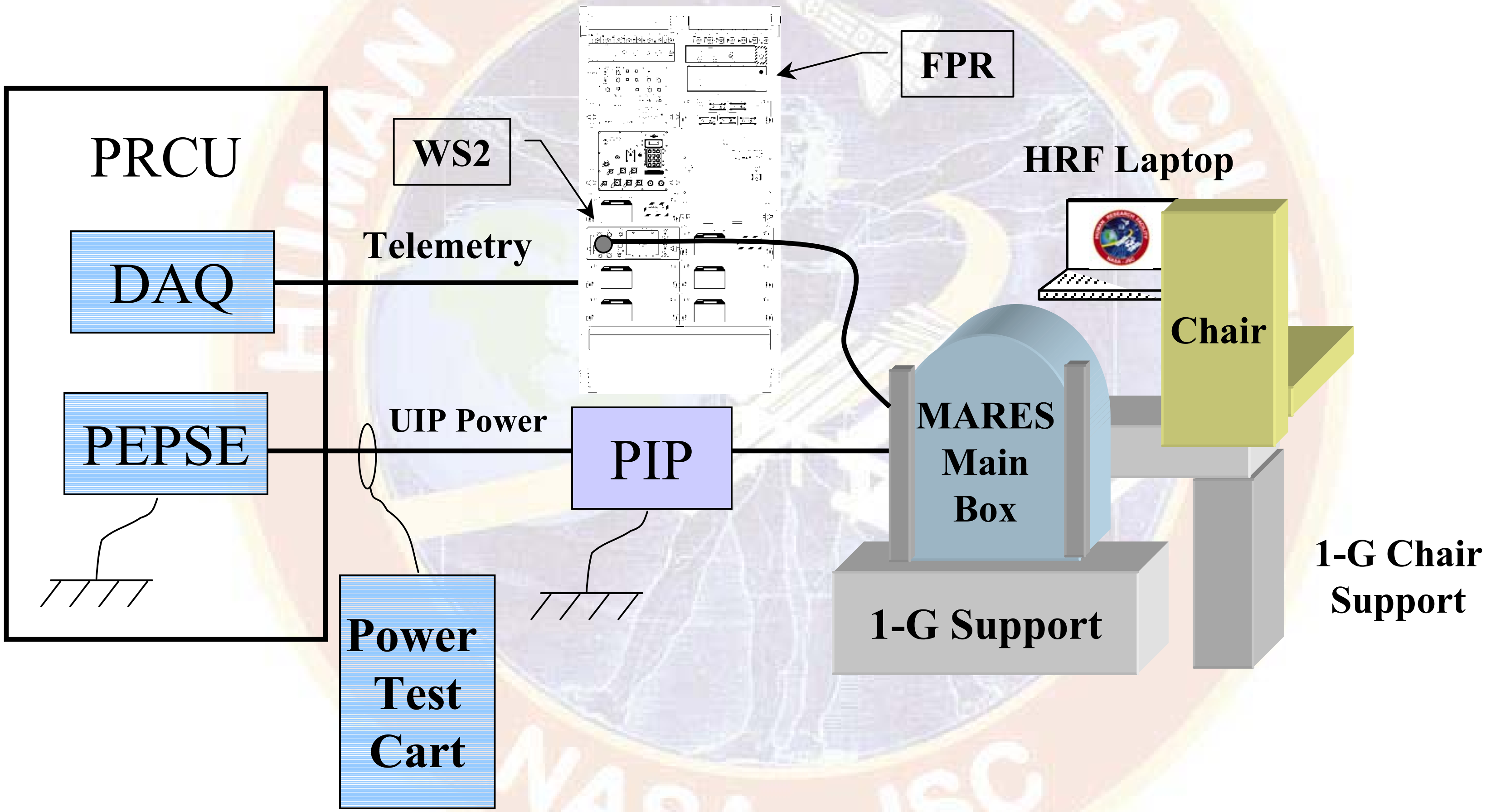
Integration: KSC Pre-launch Activities

- Pack and Ship (L-7)
  - Logistics activities include GSE required at KSC
- KSC Offline (L-6)
  - Post-ship functional test in integrated configuration
- KSC Online - PTCS (L-5)
  - Mission assurance testing against KSC-negotiated requirements
- CEIT and Bench Reviews (TBD)
- Launch Prep
  - Assemble to Launch Configuration Drawing
- MPLM Installation Ops (L-4)
  - Weight & CG taken during MPLM loading using RID

Integration: Systems Integration

- **Product Life Cycle Support Activities**
  - **Develop Modes of Operation for analysis and ICD**
  - **Baseline Scenarios for testing and analysis**
  - **Coordinate between verification sponsors and test conductors**
  - **Document system performance**
  - **Monitor performance for anomalies and process improvement**
  - **Support launch and landing of consumables and new manifests**

Integration: Test Configuration



Integration: Test List (Preliminary)

- Tested in integrated configuration to support VRDS closure
- Power Compatibility (ISS/PRCU-MARES-PIP)
  - Interface B (3.2.1.1.1) and Interface C (3.2.1.1.2)
  - Soft Start/Stop RPC (3.2.2.3) and RPC Circuit Protection (3.2.2.6)
  - Surge Current (3.2.2.4) and Impedance (3.2.2.7)
  - Power Profile
- C&DH (ISS/PRCU-FPR/WS2-MARES)
  - Integrated Telemetry Demonstration and Data Capture
  - MAC Address Capture and IP Address confirmation (3.3.6.1.2)
- Human Factors: Mechanical (3.12.4), mates (3.1.1.6) , and protrusions (3.1.1.7)
- Safety: sharp edges (3.12.9.2), and touch temp (3.12.3.2.1)
- Rack Maintenance Switch (3.2.5.2, 3.3.10.1, 3.3.10.3)
- No test: acoustics, EMI, thermal, FDS, video, H&S

HRF MARES Rack Design

Mechanical Design

- International Standard Payload Rack (ISPR) Modifications
- Payload Integration Structure
- Stowage Drawer
- Power Interface Panel
- Launch Configuration
- Stowed Configuration
- Deployed Configuration
- Materials List and approval

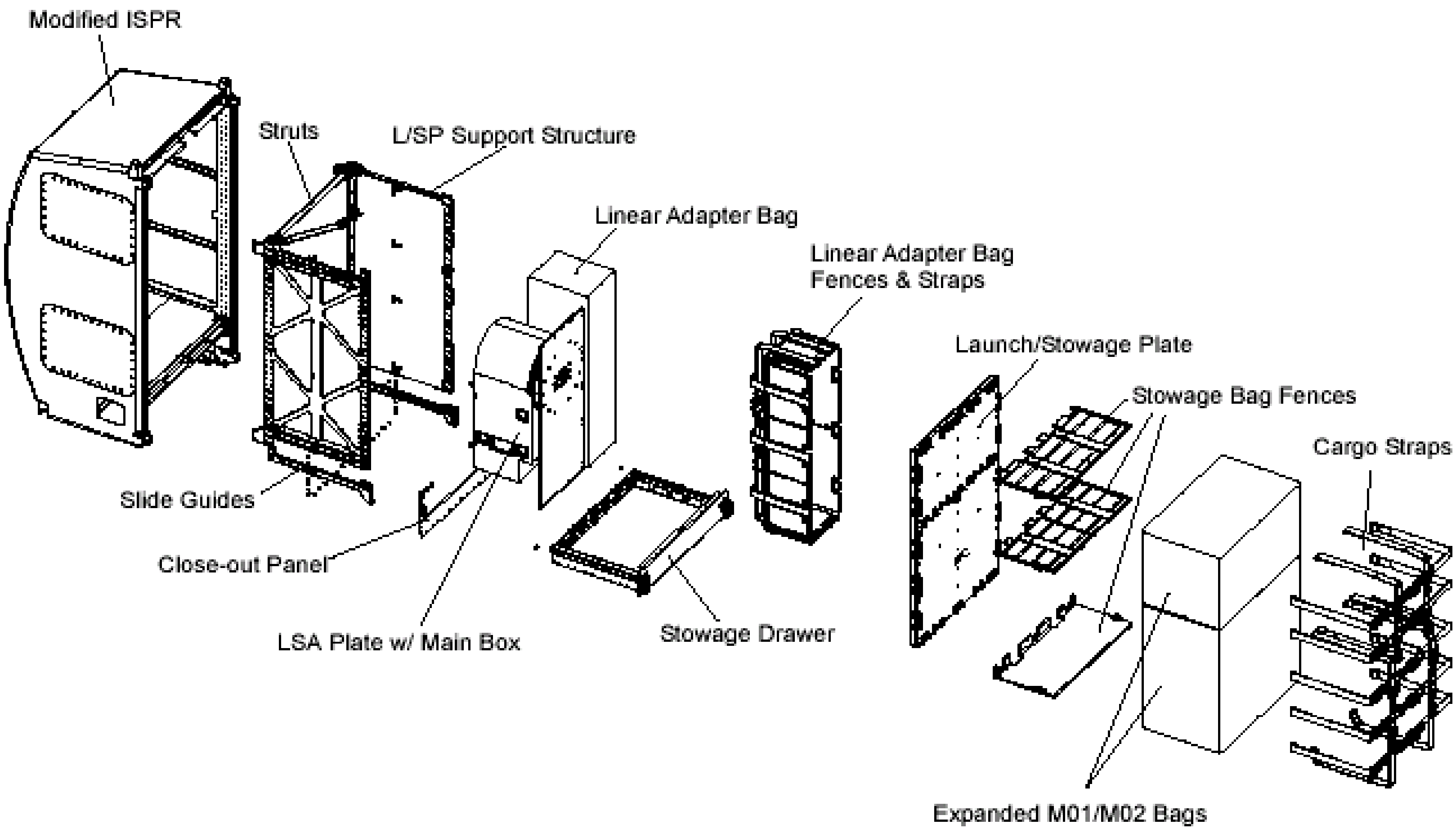
ISPR Modifications

- Remove Front and Rear Center Posts and Brackets
- Remove Upper Shelf and Brackets
- Install Upper Shelf Horizontal Member in the ISPR
- Remove Utility Closeout Panels and Hardware
- Replace the three Pressure Relief Assemblies with Hole Plugs
- Install Post Stabilizer Sets

Rack Structure Components

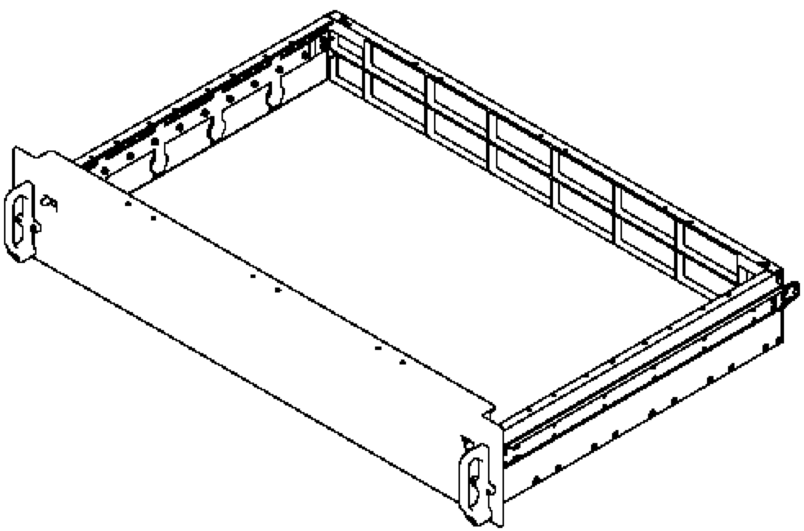
- Launch/Stowage Plate (L/SP)
- L/SP Support Structure Assembly
- L/SP Strut Assemblies
- Close Out Panel
- Slide Guide Assembly
- Stowage Drawer
- Stowage Bag Fences
- Launch Support Adapter (LSA)
- Stowage Bags and Cargo Straps

Exploded Launch Configuration



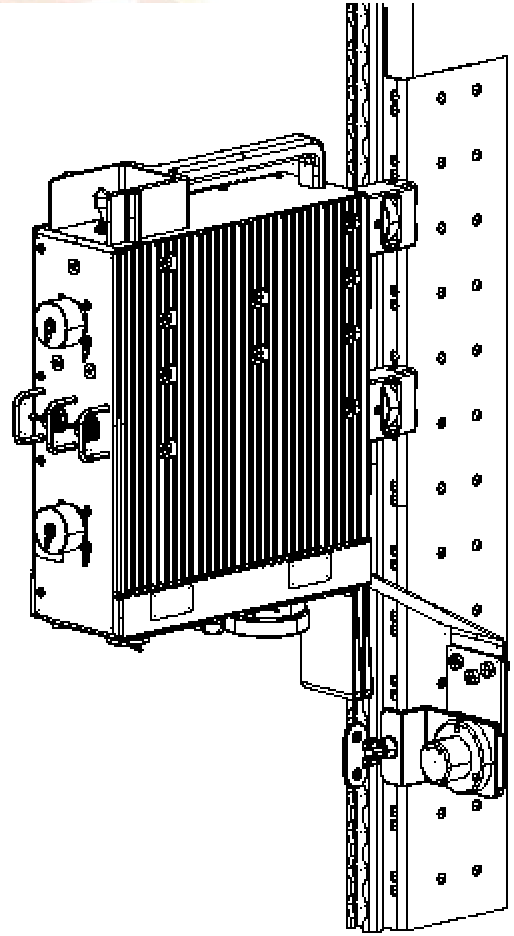
Stowage Drawer

- Dimensions 39” X 24” X 7” outside.
- Internal volume of approx. 2 cubic feet.
- Handles and Slides are similar to other HRF Drawers.

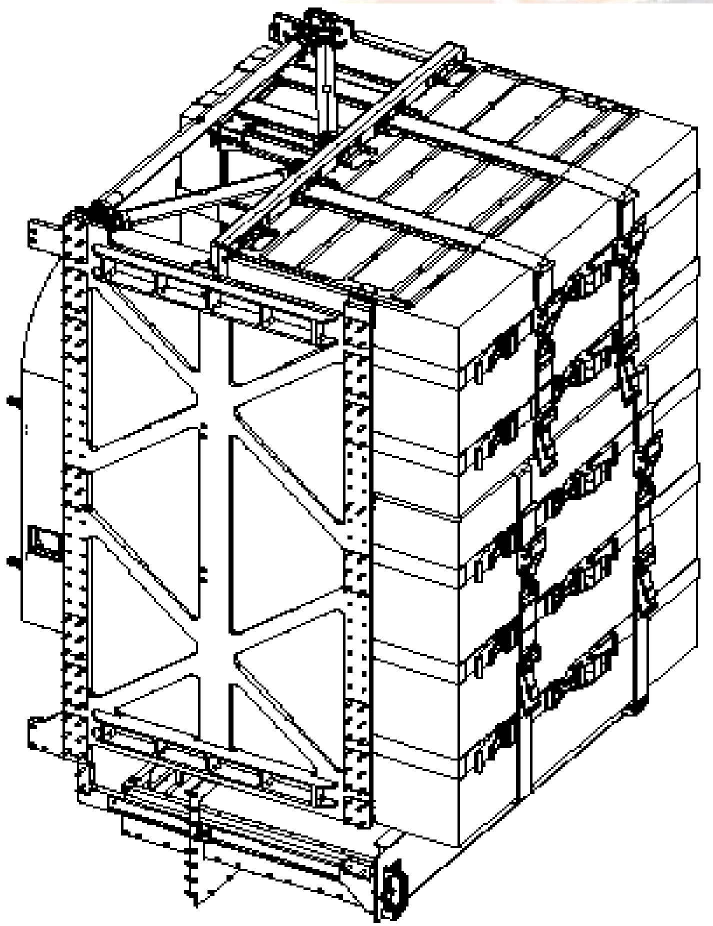


Power Interface Panel

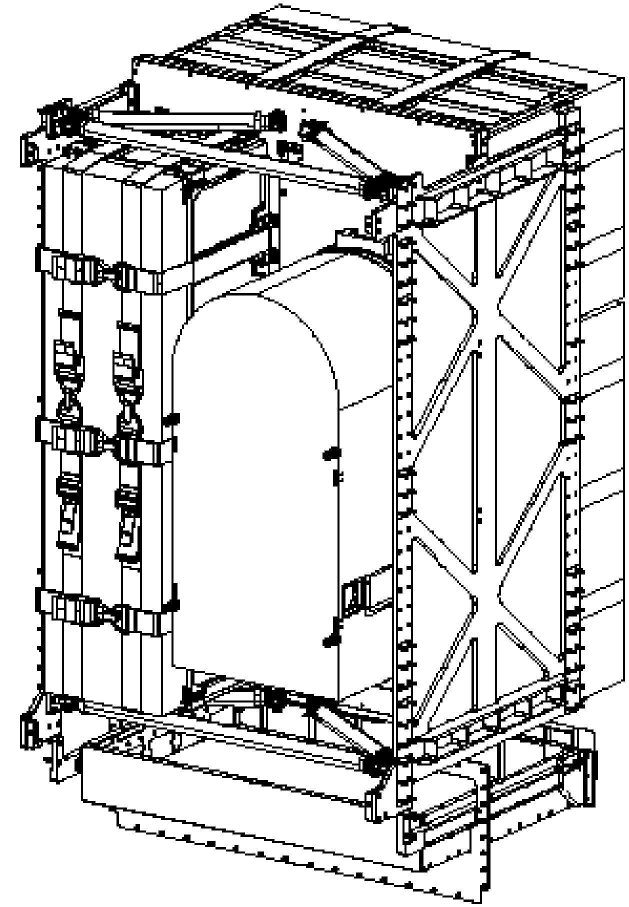
- Power Interface between the ISS power resources and the MARES
- Dimensions : 3.5” X 9.0” X 10.5”
- Built-In Fins on the Chassis for heat dissipation
- Less than 30% Internal free air volume
- Seat Track Mounted
- Functional characteristics noted in the Electrical Section



Launch Configuration Without Rack

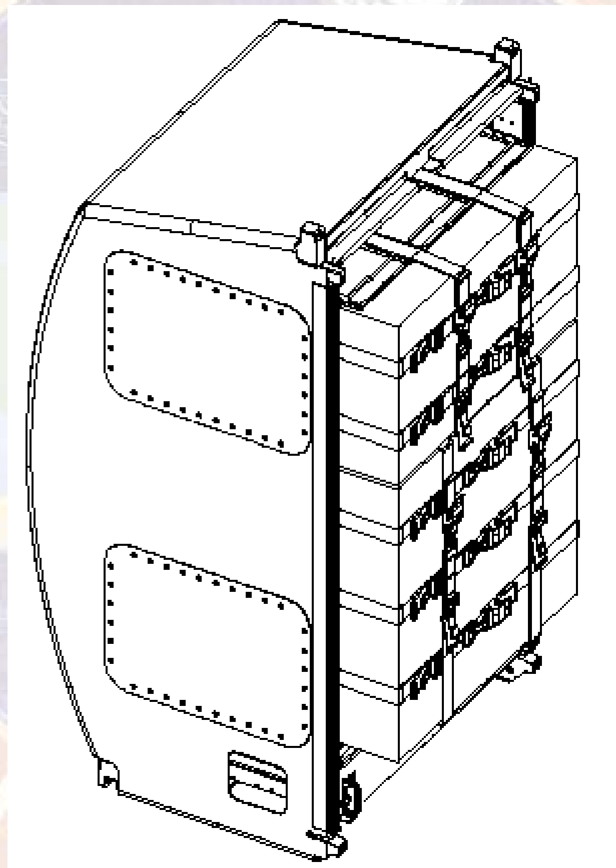


Launch/Stowage Front ISO View

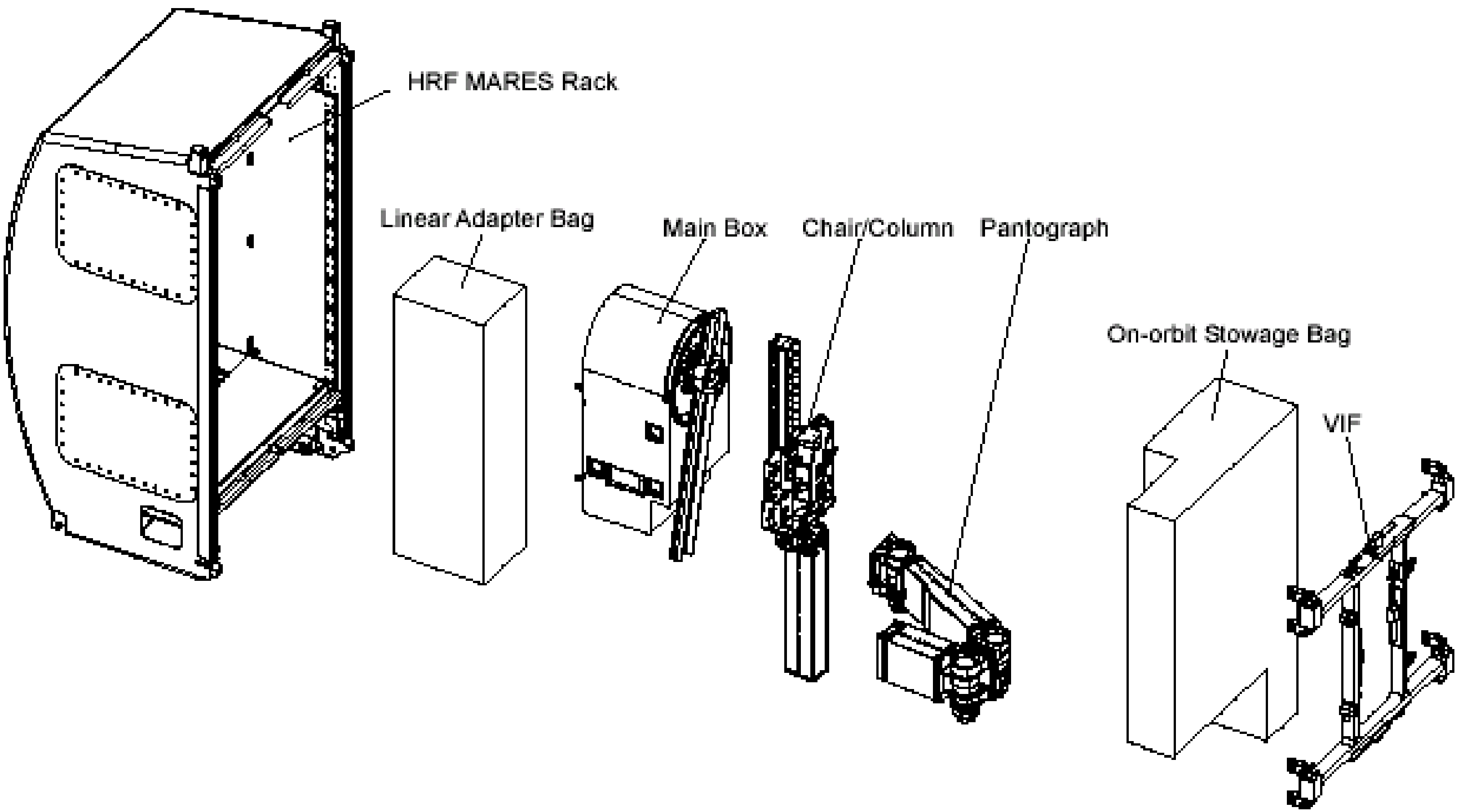


Launch/Stowage Rear ISO View

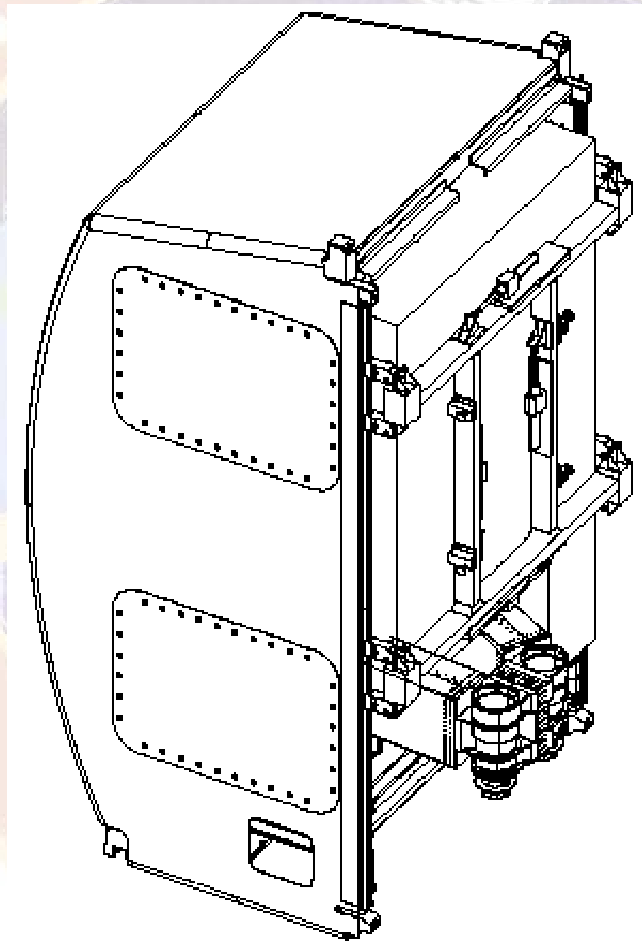
Launch Configuration With Rack



Stowage Configuration Exploded

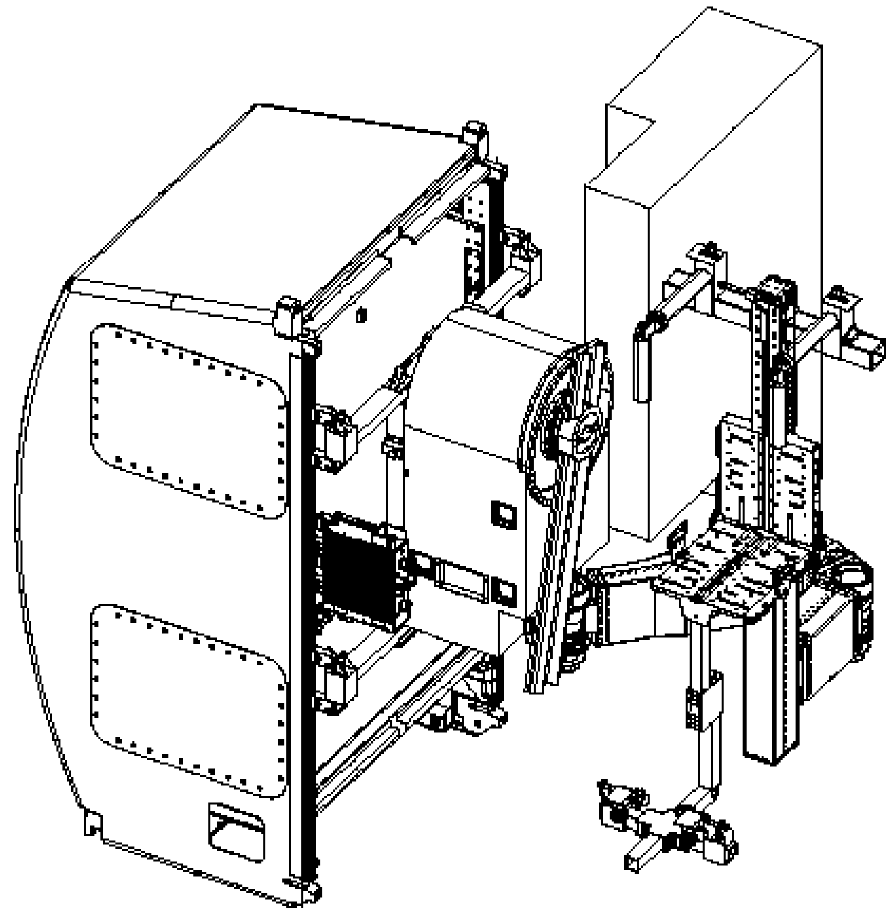


Stowage Configuration



Deployed Configuration

- VIF mounted on seat tracks on front face of HRF MARES Rack
- Motor Box, Chair, and Pantograph attached to VIF
- Accessories deployed as needed
  - Configure associated hardware (PC, R2WS)
- PIP and Cables deployed
  - Mounted to seat tracks
  - Ground Strap Attached



HRF MARES Rack

Materials and Processes

Material Requirements

- Materials and Processes shall meet the requirements of SSP 30233 Revision F (Space Station Requirements for Materials and Processes) as implemented by JSC 27301D (Materials Control Plan for JSC Flight Hardware)
- Materials shall be selected from the materials listed in the Materials and Processes Technology Information System (MAPTIS) and MSFC-HDBK-527F/JSC 09604 that are "A" rated in their use environment. Any non-A-rated materials have to be covered by an approved Materials Usage Agreements (MUAs)

Materials Assessment for HRF MARES Rack

Metallic Materials:

Components Name	Materials	Processes	Matl Code	Corr	SCC	Remark
Mounting Pad, Latch Body, Latch Box, Latch Rod, Attchment Bracket, Clip, Strut, PWB Heat Sink, Long Spacer, Flange, Cover, Clamp Knob, Handle, Retainer, Handle, Strap End, Wing, Bracket Assy, and Stud Driver	Al 6061-T651	Anodized per PRC-5006, Type II, Class 1	50278	B	A	MUA Rationale Code 610*
Motor Box, Launch/Stowage Plate, Fence Hinge, Fence Assy, Corner Fitting Assy, Tee Fitting, Support Structure, Slide Guide, Utility Close Out Panel, Chassis, Cover, Mounting Body, Slide Bar, and Panels	AL 7075-T7351	Anodized per PRC-5006, Type II, Class 1	50669	B	A	MUA Rationale Code 610*
Rack Support Structure Shim	AL 5052-H32	Alodine per PRC-5005, Class 1A	10112	B	A	MUA Rationale Code 610*

* Code 610: Surface of metal not A-rated for corrosion is coated which meets the requirement of MSFC-SPEC-250A.

Materials Assessment for HRF MARES Rack

Components Name	Materials	Processes	Matl Code	Corr	SCC	Remark
Mounting Screw, Connector Captive Screw	CRES A286 (AMS 5737)	Age harden to 140 Ksi. Passivate per PRC-5002.	53426	A	A	Acceptable
Dowel Pin, Spring Plunger, Pivot Pin, Knob, Pin, Strud Fitting, Strut Nut, Guide Pin, Standoff, Screw, Receptacle, Ground Braid, Handle, Stop Release, Retention Pin, Stud, and Self-locking Insert	CRES 300 Series	Passivate per PRC-5002.	10506	A	A	Acceptable
Compression Springs	CRES 302, Spring Temper	Passivated per PRC-5002	53803	A	A	Acceptable
D-Ring. Buckle, and Adjuster Assembly	SAE 4130 Alloy Steel	Quenched and tempered to HRc 35, plated with chrome.	50912	B	A	MUA Rationale Code 610*

* Code 610: Surface of metal not A-rated for corrosion is coated which meets the requirement of MSFC-SPEC-250A.

Materials Assessment for HRF MARES Rack

Nonmetallic Materials:

Components Name	Materials	Material Code	Flammability	Toxicity	Remark
Linear Adapter Bag, M01 & M02 Bag, Label	HT90-40 Nature Nomex	05479	A	K	Acceptable
Webbing	Vectran VCT-230	04584	A	K	Acceptable
Velcro	Nylon	61397	C	K	MUA Rationale Code 105**
Epoxy primer base for wet installation	Super Koropon Epoxy Primer 515-700	05015	A	V	Acceptable
Tape	3M 361 Fiberglass	06188	A	K	Acceptable
M01 & M02 Bag	Chemglas	60867	A	K	Acceptable
M01 & M02 Bag	L-200 Foam	01164	X	K	MUA Rationale Code 112***
PWB Insulator Sheet	Kapton K10AC	65086	A	K	Acceptable
SUP/UOP PWB	Epoxy Fiberglass per IPC-4101/24	05543	A	K	Acceptable

** Code 105: Minor usage; no propagation path or ignition source.

*** Code 112: Not A-rated for flammability is unexposed and covered with a non-flammable material

Materials Assessment for HRF MARES Rack

Nonmetallic Materials (Continued):

Components Name	Materials	Matl Code	Flammability	Toxicity	Remark
Front and End Runer	Delrin	68624	X	K	MUA Rationale Code 105**
Top and Bottom Runer, Driver Retainer	Teflon	00551	A	K	Acceptable
Dry Film Lubricant	Everlube 620C	63943	A	K	MUA for Flammability
Adhesive	DC 3145	05247	A	A	Acceptable
Cable	Teflon Insulation Wire per MS22759	01188	A	K	Acceptable
Expando Sleeve	HR-1/4 ECTFE	05479	A	K	Acceptable
Cable Marker	Tedlar Roll Film	05479	A	K	Acceptable
Cable Tie	Tefzel	62742	A	K	Acceptable
Black Marking Ink	73X	00010	A	A	Acceptable

Materials Assessment for HRF MARES Rack

Conclusion:

1. **Per preliminary drawings, the metallic and non-metallic materials used in this HRF MARES Rack Assembly are acceptable for flight**

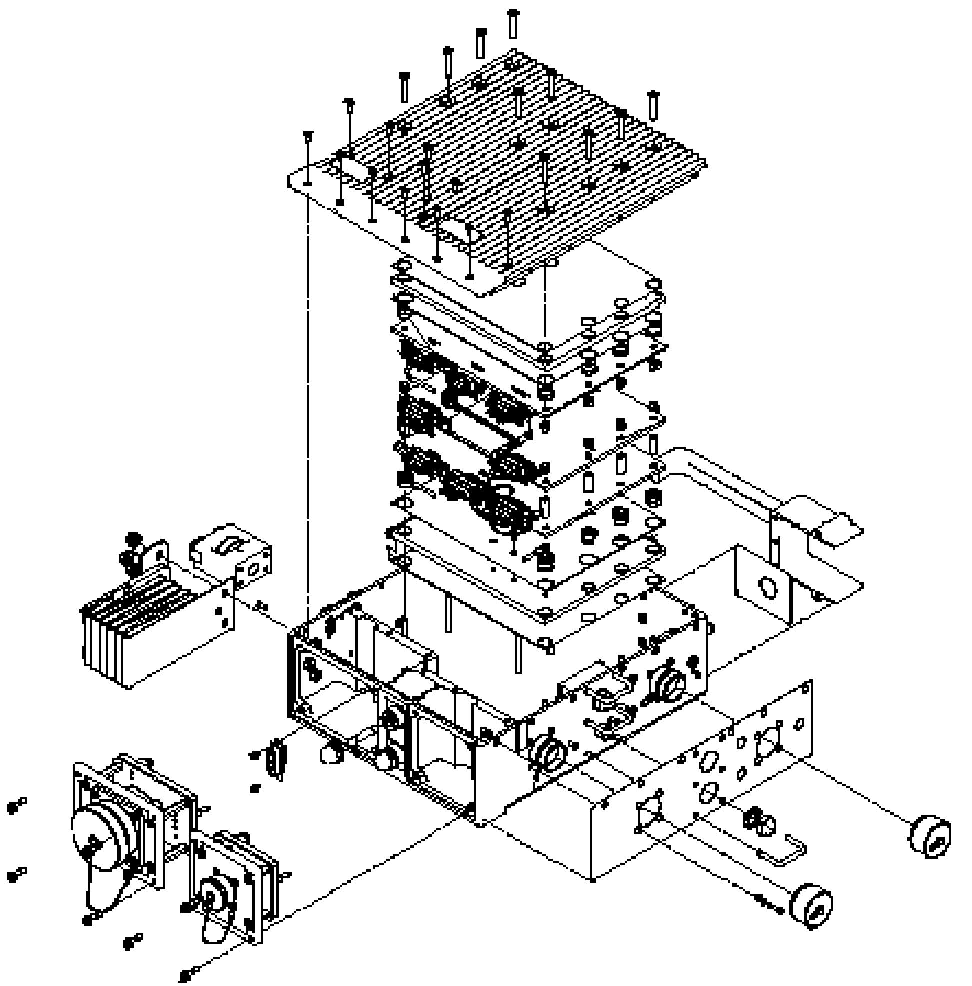
2. **Self-locking Inserts are used in this design, it meets positive locking feature requirements per JSC 27301D Para. 5.6.5.1**

Electrical Design

Power Interface Panel Overview

- **Power Interface for HRF MARES RACK**
  - Interface to UOP or UIP for 120 VDC
  - Meets station trip, inrush, and impedance requirements, independent of load
  - Provides low output impedance to reduce load input impedance requirements
  - Rack maintenance Switch

Power Interface Panel

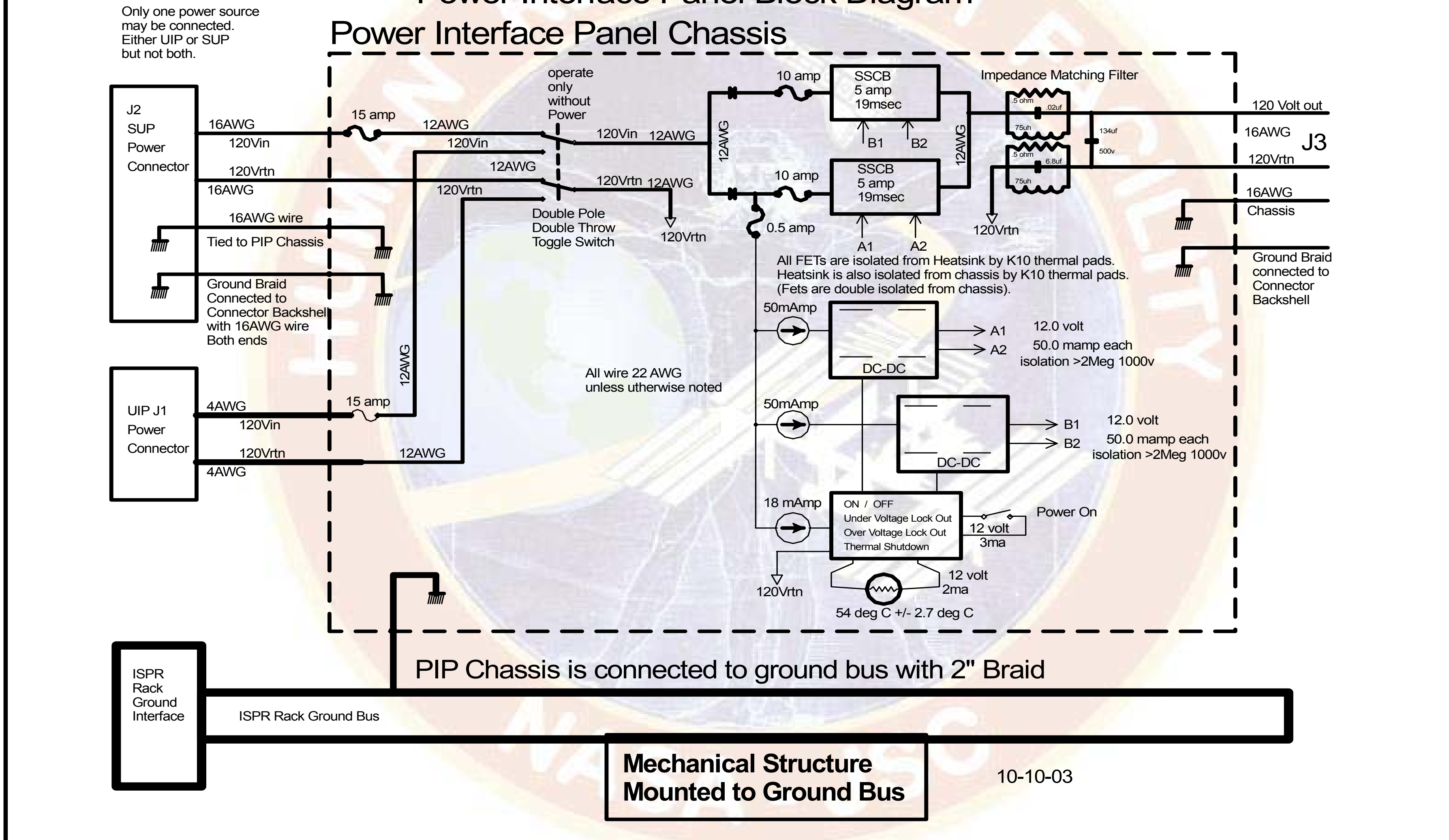


Power Interface Panel

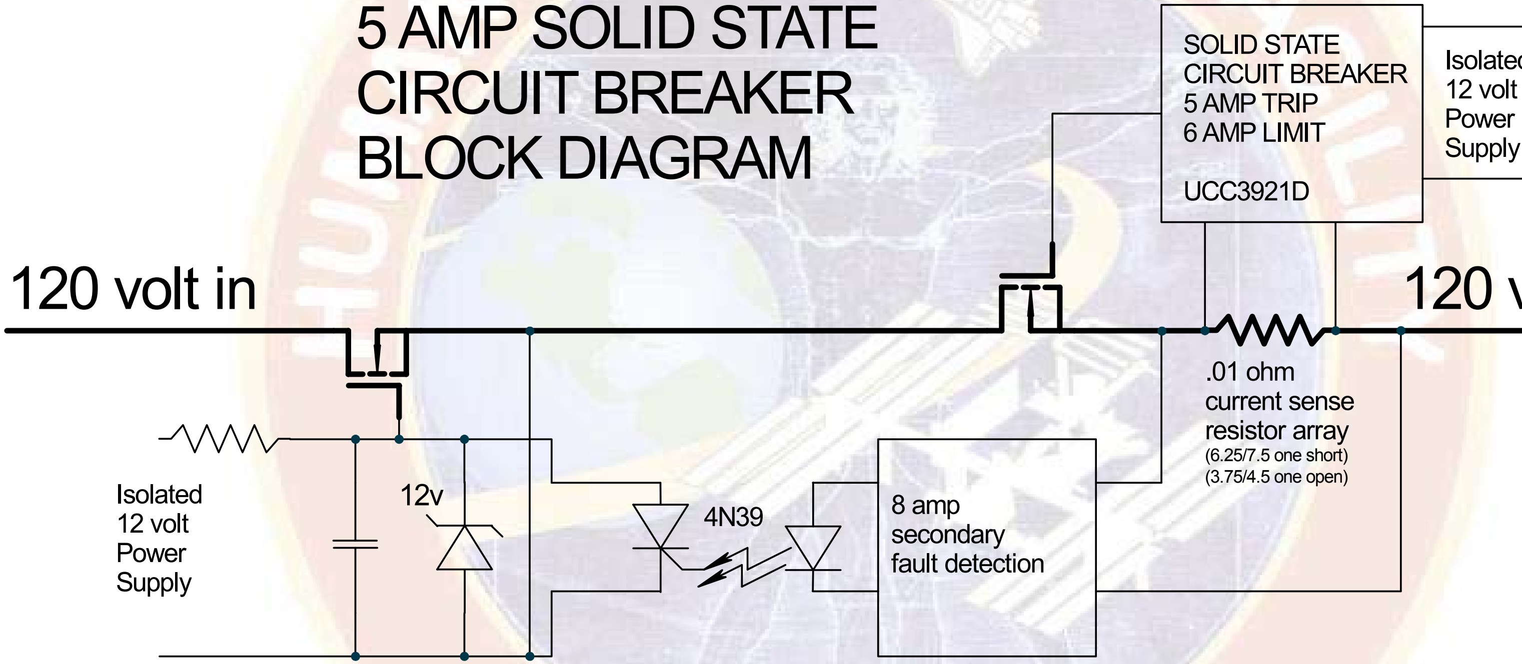
Power Interface Panel Design

- 10 amp Solid State Circuit Breaker
- Rated for 6 amps steady state current
- Limits fault current to 12 amps within 1millisecond
- Provides low output impedance
- Meets Station Requirements
  - Impedance
  - Inrush Current
  - Surge Current
  - Fault Current
  - Trip time
- Power Dissipation is 49.5 watts at 9 amps load. (27.5 watts at 5 amp load) (33 watts at 6 amp load)
- Thermal cutoff switch trips at 47 +/-2 deg C case temp

Power Interface Panel Block Diagram



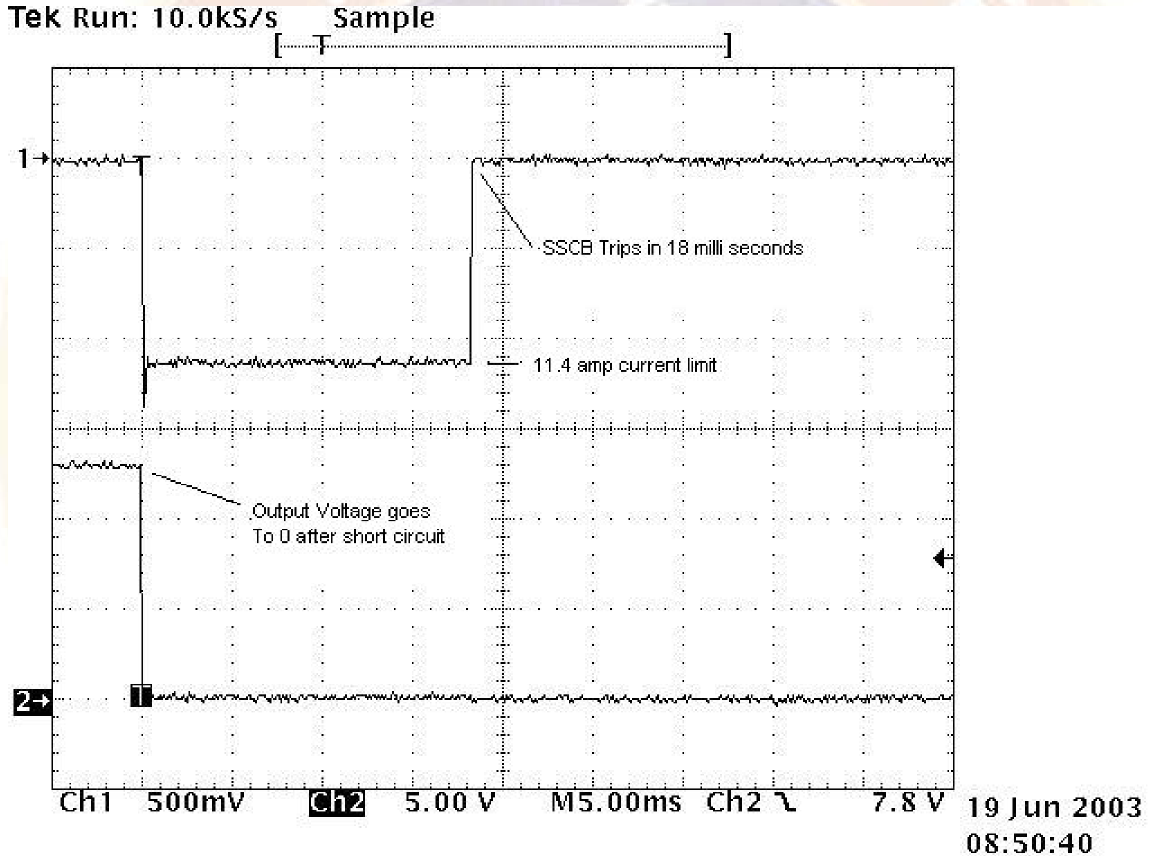
5 AMP SOLID STATE CIRCUIT BREAKER BLOCK DIAGRAM



PIP Prototype Testing Results

- Passed impedance test using PRCU and Impedance Rack
- Passed fault current and inrush current test
  - Fault current was measured to be 12 amps
  - Trip time was measured to be 18milliseconds
  - Fault current reached 12 amps within 150usec
- Passed touch temperature test
  - Touch temperature: 47.1 deg C at 30 deg C ambient with no air flow
  - Thermal analysis shows touch temperature is less than 49 deg C at 30 deg ambient temp

PIP Fault Current



Channel 1 is SSCB input current 5 amps per division

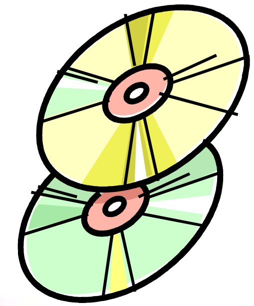
Challel 2 is SSCB output voltage 50 volts per division

PIP EEE Parts Evaluation

- **EEE parts derating analysis has been submitted and approved.**
  - **The input fuses were changed from 12 to 15 amps per EEE parts recommendations.**
  - **The 15 amp fuse still does not meet the 50% derating for an input current of 9 amps.**
    - **This fuse is redundant to the SSCB which trips at 10 amps and although it does not meet the 50 percent derating requirement, EV5 recommends it not be changed because there is sufficient margin between the 9 amp nominal current and the 15 amp rating.**

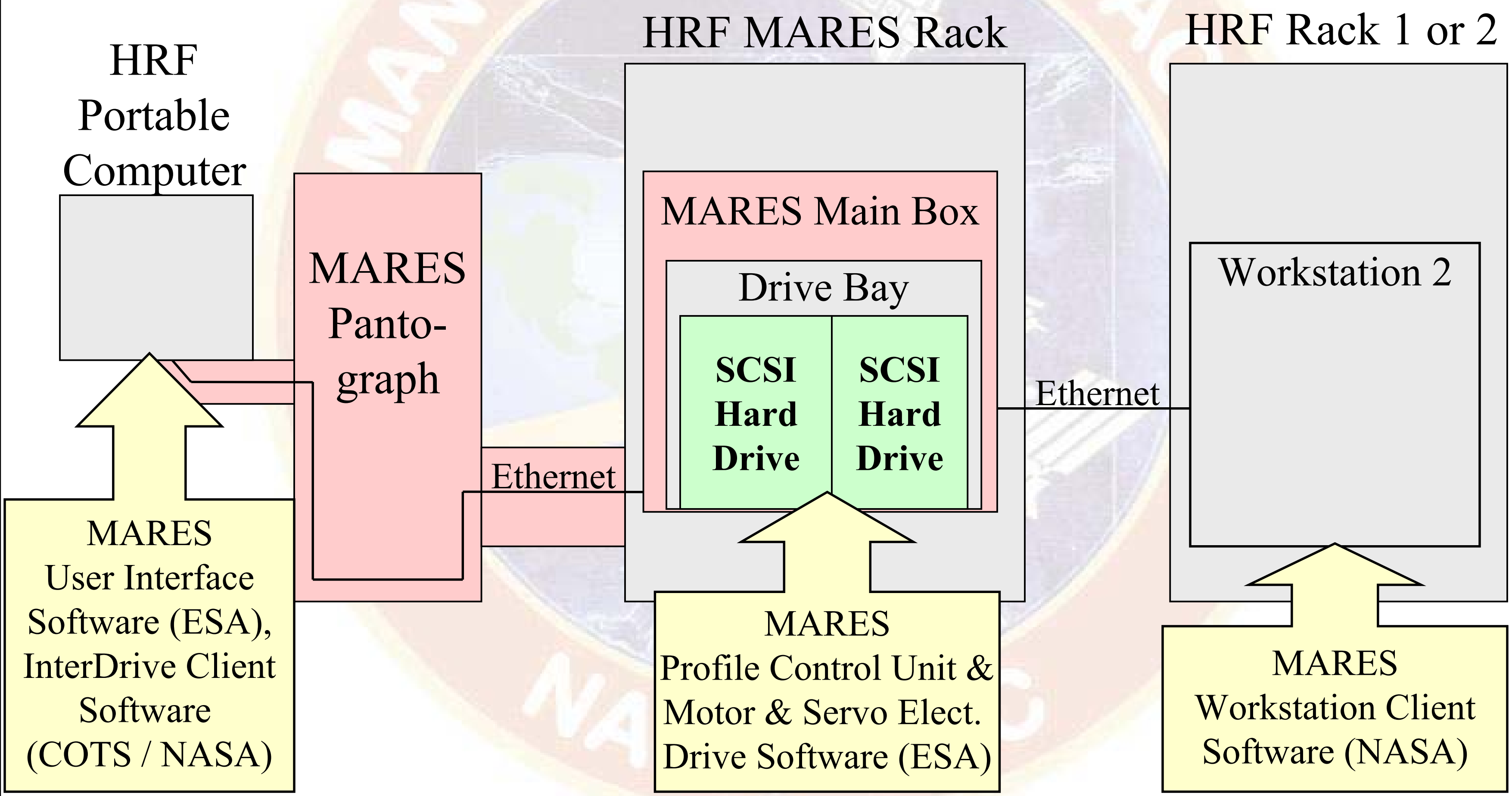
Software

MARES Software Overview

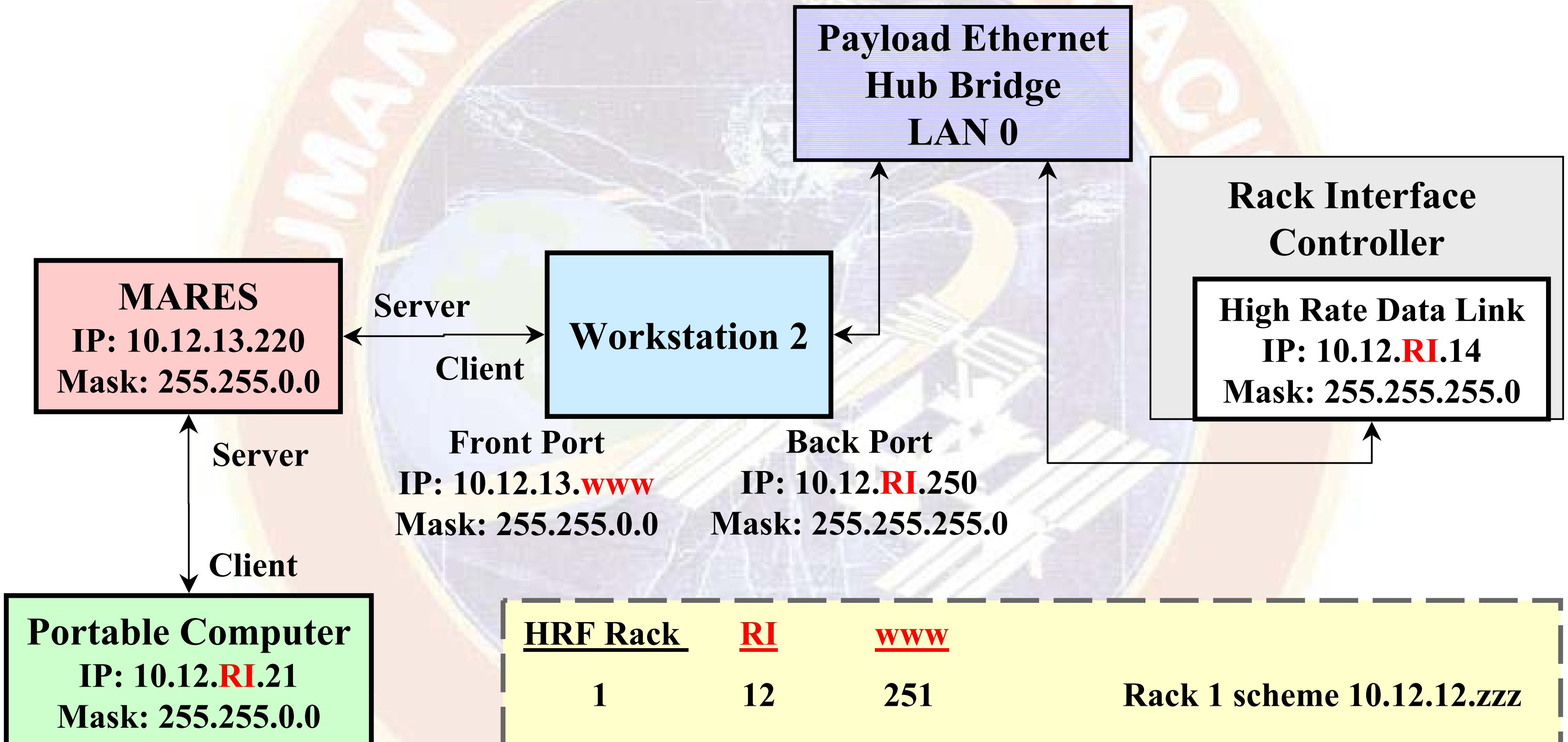


- **User Interface S/W**
  - Developed by ESA
  - Portable Computer
  - Provides the MARES crew interface
  - Display review complete
- **InterDrive Client, Ver. 7.1.0**
  - COTS purchased by NASA
  - Portable Computer
  - Maps MARES hard drives to Portable Computer
- **Profile Control Unit S/W**
  - Developed by ESA
  - MARES Main Computer
  - Performs MARES experiments
- **Motor & Servo Drive Electronics S/W**
  - Developed by ESA
  - Embedded software
  - Controls the MARES motor
- **Workstation Client S/W**
  - Developed by NASA
  - Workstation 2
  - Receives data from MARES & downlinks through Common Software

MARES Software Environment



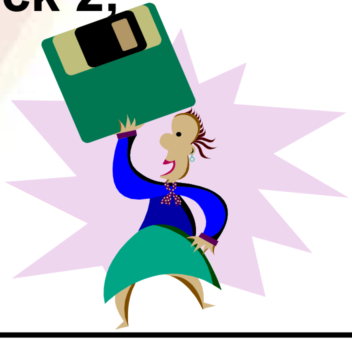
MARES Ethernet TCP/IP Address Scheme



HRF Rack	RI	www	
1	12	251	Rack 1 scheme 10.12.12.zzz
2	16	252	Rack 2 scheme 10.12.16.zzz
			HRF Deployed 10.12.13.zzz

Issues Resolved With MARES TCP/IP Scheme

- MARES is able to interface with Rack 1 or Rack 2 without changing its IP address or subnet mask
- A new subnet (10.12.13.x) was defined for deployed items needing to interface with Workstation 2 front panel Ethernet
- Rack 1 Portable Computer can interface/control Rack 2, and vise versa

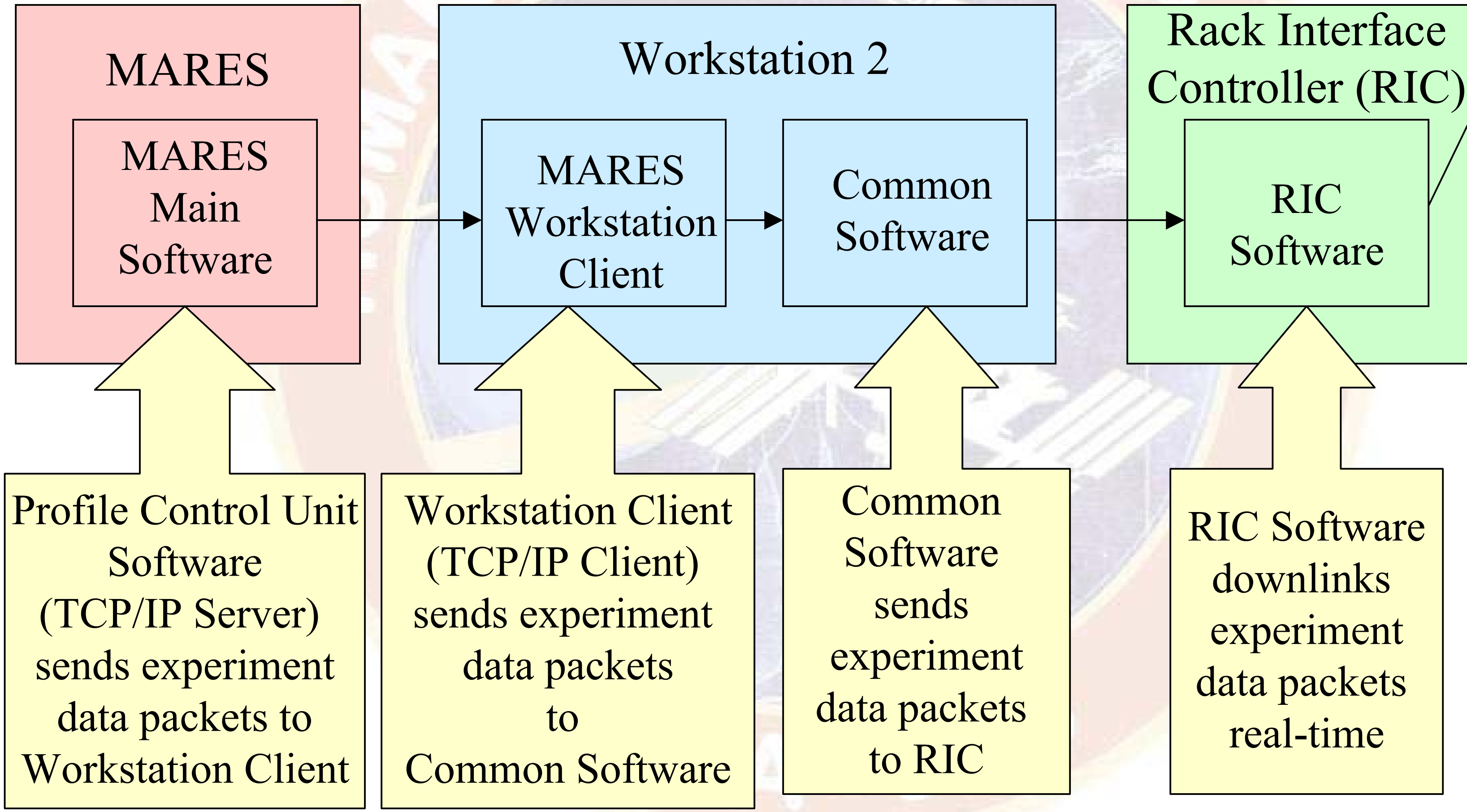


HRF MARES Rack System Design Review

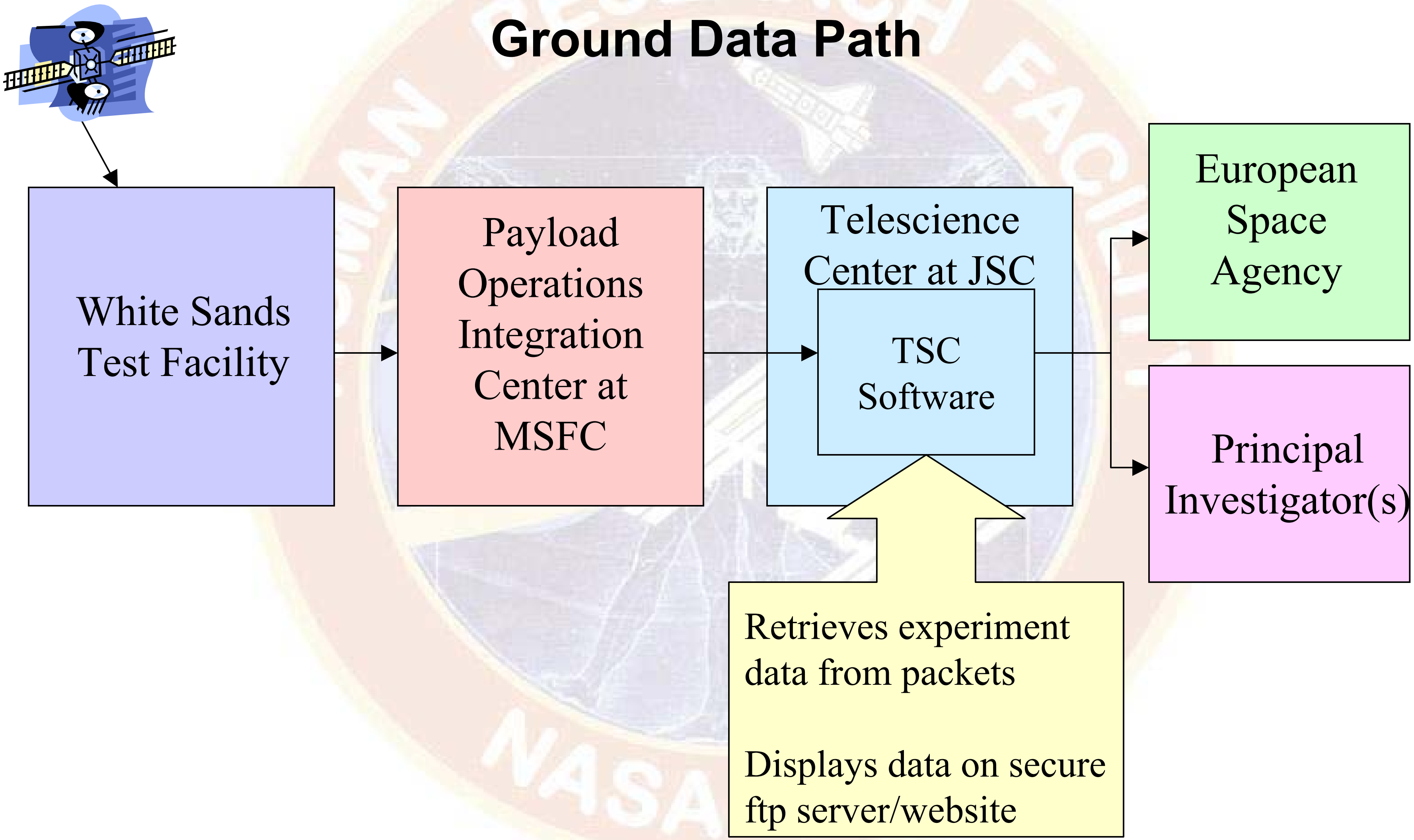
Human Research Facility (HRF) Project

Samme Lansdowne | **12/16/2003**

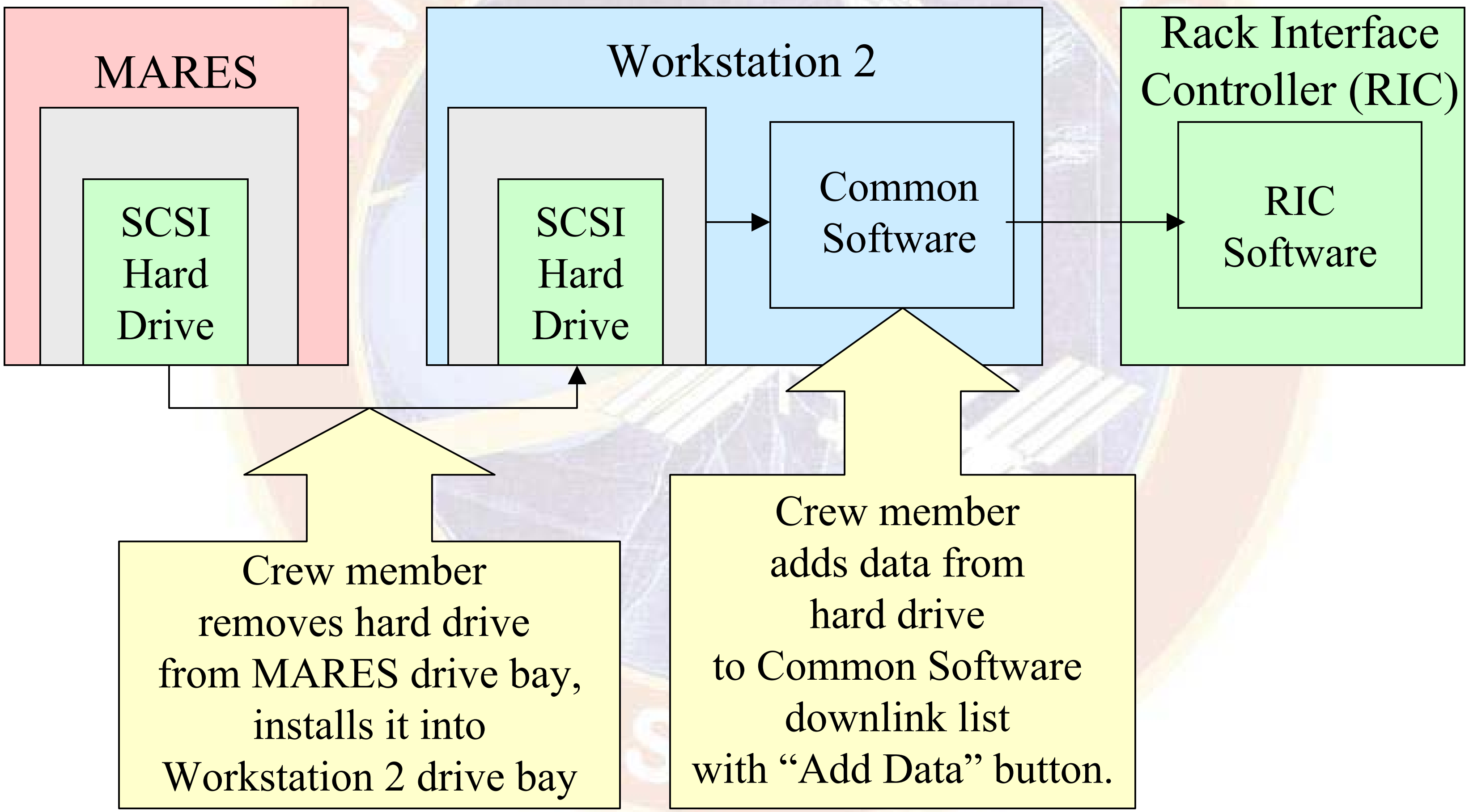
Real Time Data Path



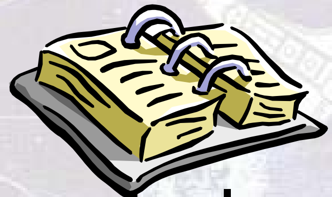
Ground Data Path



Alternative Data Path



MARES Workstation Client Software History



The Workstation Client software development was not included in the MARES Rack System Requirements Review (SRR), conducted on Dec. 18, 2002 because the requirement to develop this software was established after the SRR.

The Workstation Client software requirements were presented at a Software Review on July 21, 2003. A draft copy of the Software Requirements Specification (SRS) document was available at the review.

Formal RIDs will be accepted against the Software Requirements Specification (SRS) at this System Design Review (SDR).

Software Control Plan

- **Software Development Plan (SDP) for the Human Research Facility, LS-71020B**
  - **Code Review – Software Quality Assurance (SQA), developer community**
  - **Unit Testing - developer**
  - **Integration Testing – independent tester**
  - **Qualification Testing – independent tester, SQA, TPS**

- **Software Configuration Management Plan and Procedure for the Human Research Facility, LS-71020-1**
  - **Razor, HRF configuration management tool is used**
  - **Qualified software is placed into bonded storage**

Software Deliverable Documents

- **Software Requirements Specification, LS-71090-2**
  - States requirements for the software
  - Requirements are derived from HRF Interface Specification (MARES-0000-SP-103-NTE), MARES HRD (LS-71053-1), MARES Rack HRD (LS-71090-1)

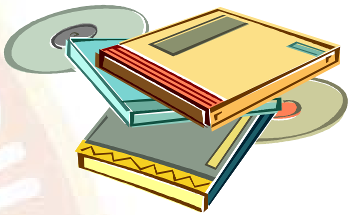
- **Software Test Plan (STP), LS-71090-3**
  - Describes the functional requirements satisfied by the software
  - Details the procedures for satisfying those requirements

Software Deliverable Documents (Cont.)

- **Chapter in the HRF Software Design Document (SDD), LS-71083D**
  - Identifies the requirements met by each software section
  - Describes the software inputs, outputs, global data, interfaces, and general design approach

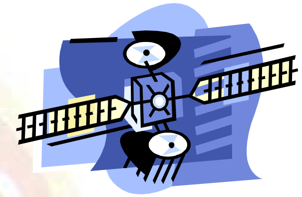
- **Version Description Document (VDD)**
  - Lists the versions of each software file that is being certified
  - Details the software installation procedure
  - Identifies any known “bugs” or problems

MARES Workstation Client Software Overview



- Software will run on Workstation 2
- Software will receive MARES experiment data via Ethernet, and send it to Common Software for real-time downlink
- Software will be launched and terminated with ground commands through Common Software (new feature)
- Software will operate without crew intervention; without keyboard or monitor attached to the Workstation 2
- Software will have no user interface or visual displays

Real-Time Data Format



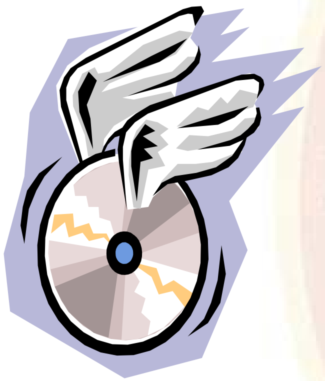
- Real-time data for the MARES Workstation Client shall be formatted as defined in the HRF Interface Specification – MARES and MARES Rack System. (MARES-0000-SP-103-NTE)

- MARES real-time data will not be in Life Science Data System (LSDS) format

- Telescience Support Center has agreed to process, display and save MARES real-time data in MARES-specific packet format

- Real-time, batch downlink, and post-flight media (SCSI hard drive) data formats will match

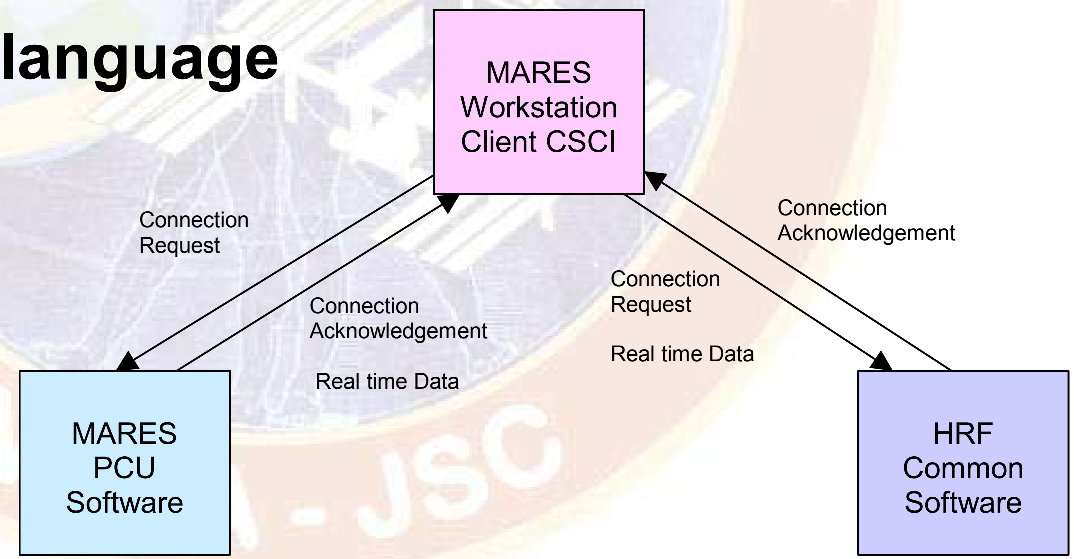
MARES Experiment Data Downlink



- MARES Workstation Client Software shall connect to Common Software with a different experiment ID for each MARES experiment
- Each MARES experiment's data is easily identified and separated on the ground for different Principal Investigators

MARES Workstation Client Computer Software Configuration Item (CSCI)

- Accepts MARES experiment data from MARES Profile Control Unit Software
- Sends experiment data to HRF Common Software for real-time downlink
- Visual C++ 6.0 language



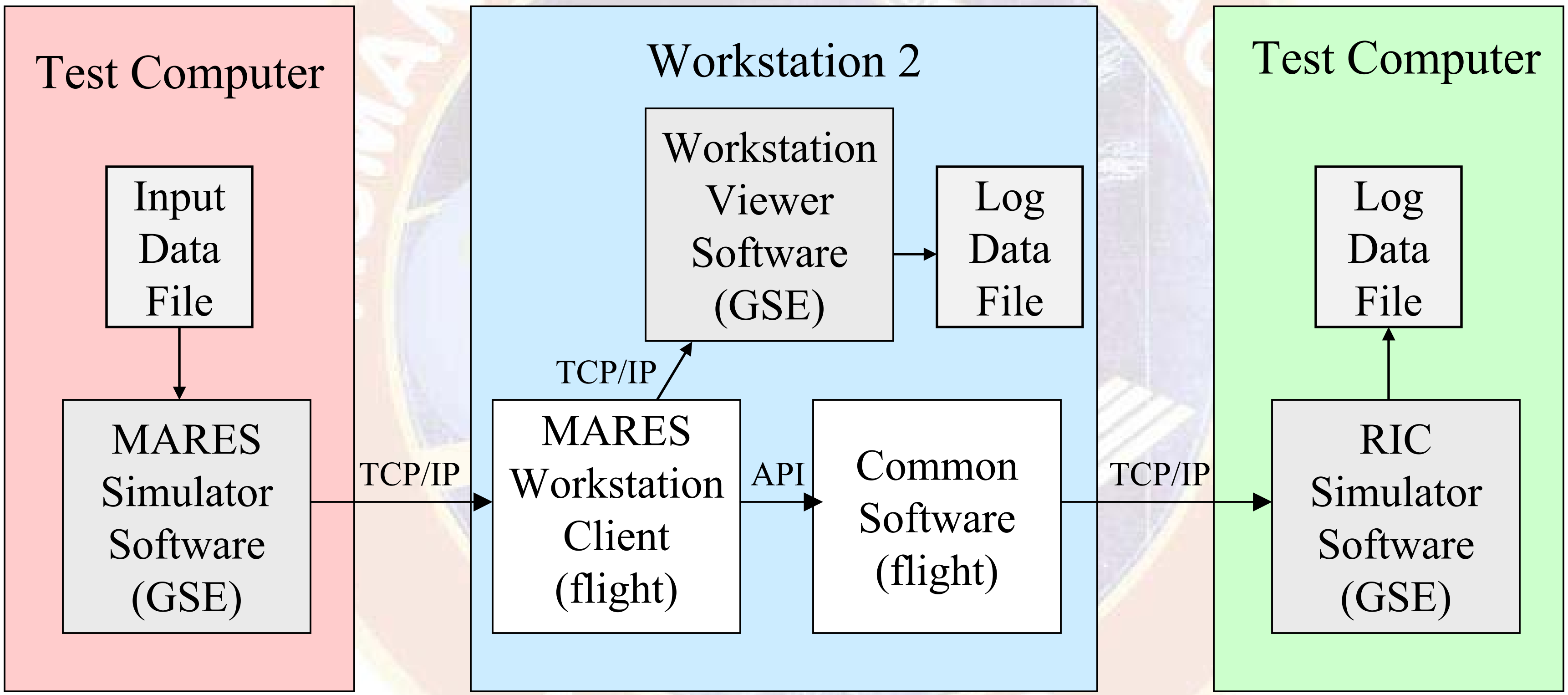
Computer Software Units (CSU)

- **Main CSU**
  - Initiates the sequence of interactions between the other CSUs
- **MARES Interface CSU**
  - Interfaces with MARES Profile Control Unit Software
- **Common Software Interface CSU**
  - Interfaces with Common Software

Test Plan

- **GSE MARES Simulator Software**
  - Reads data packets from file
  - Sends packets to MARES Workstation Client
- **Flight MARES Workstation Client Software**
  - Receives packets, sends to Common Software
  - Sends packets to GSE Workstation Viewer
- **GSE Workstation Viewer Software**
  - Will display and log packets received by MARES Workstation Client
- **GSE RIC Simulator Software**
  - Code reuse - written by Common Software developer
  - Will display and log packets received from Common Software

Test Plan (continued)



Test Plan (continued)

- When MARES system is available, it will be substituted for the MARES Simulator.
- System will be tested with the Telescience Support Center through the Bldg. 9 mockup.
- MARES Workstation Client Software will be launched and terminated with ground commands through Common Software. Testing this function will follow the same testing procedure as used for Common Software.

Stowage

MARES Rack Stowage

- **Concept layouts**
  - MARES stowage is currently divided into two timeframes… launch, and on-orbit
  - Some of the stowage will be present in both timeframes, while others will only be present for launch or on-orbit
  - One of the main goals is to stow all MARES items within the rack volume, for both launch and on-orbit periods without the need for extra volume within the ISS
  - Another goal is to minimize the unstow/setup and teardown/restow times for the crew
  - Some modifications to these concepts are expected as the MARES flight fabrication progresses

MARES Rack Stowage (continued)

- **Launch configuration**
  - **MARES launch stowage locations will consist of:**
    - **1 M01 soft stowage bag (6 MLE volume equivalent)**
    - **1 M02 soft stowage bag (4 MLE volume equivalent)**
    - **1 Linear Adapter stowage bag**
    - **1 HRF MARES Rack stowage drawer**
  - **The M01 bag will contain items that will not generally need to be "restowed" in a bag/kit on-orbit:**
    - **MARES pantograph**
    - **MARES chair/column and various components**
    - **MARES main box electronics**
    - **MARES VIF center section**
    - **Most of these items are put in place during the initial MARES deployment ops**

MARES Rack Stowage (continued)

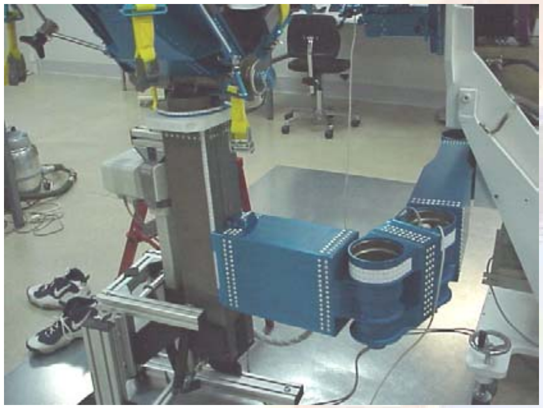
- **Launch configuration**
  - The M02 bag will contain items that will generally need to be restowed on-orbit:
    - MARES levers (long/medium/short)
    - MARES trunk adapter
    - MARES ankle restraint
    - MARES handgrip adapter
    - MARES adjustable structure(s)
    - Miscellaneous other pieces
  - The Linear Adapter stowage bag will hold:
    - MARES Linear Adapter
    - MARES press bar
    - Horizontal members of the VIF (for launch)
  - The HRF MARES rack stowage drawer will be used to house the PIP, associated cabling, and other miscellaneous support items

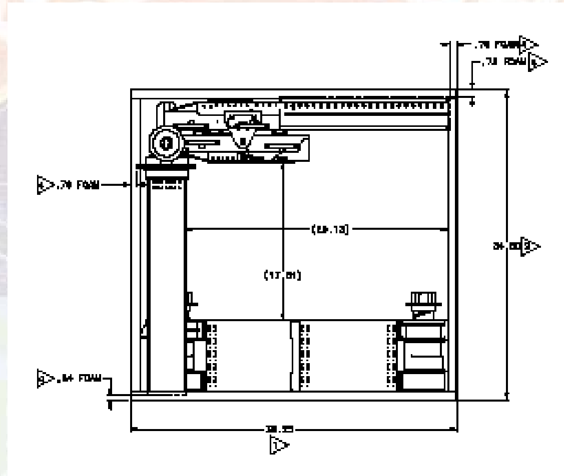
HRF MARES Rack System Design Review

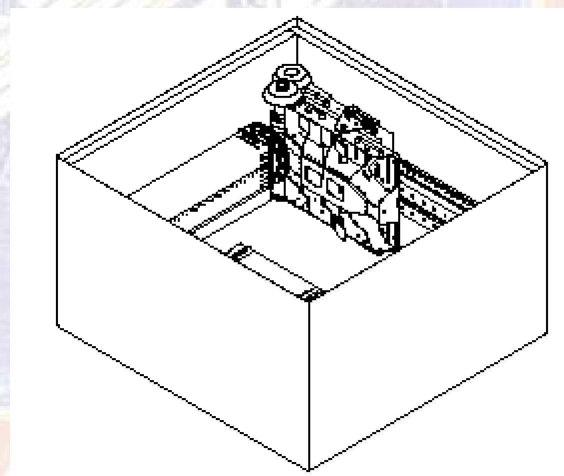
Human Research Facility (HRF) Project

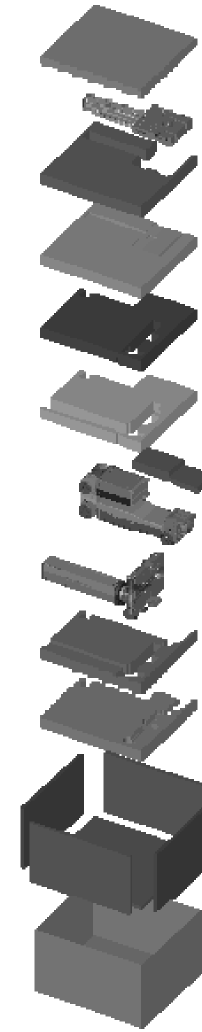
Dan Barineau

12/16/2003



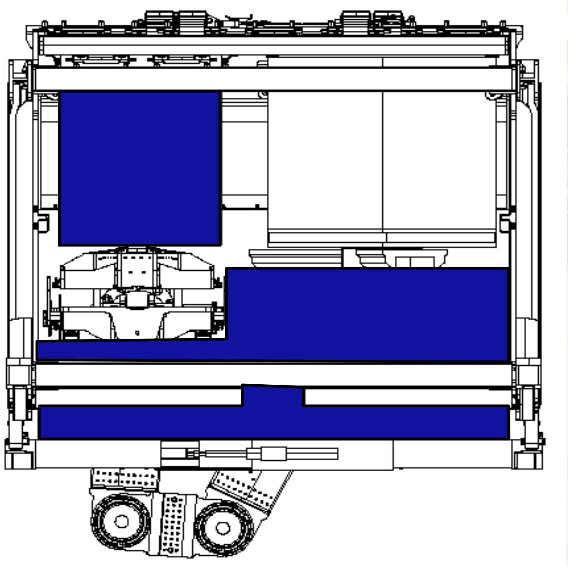


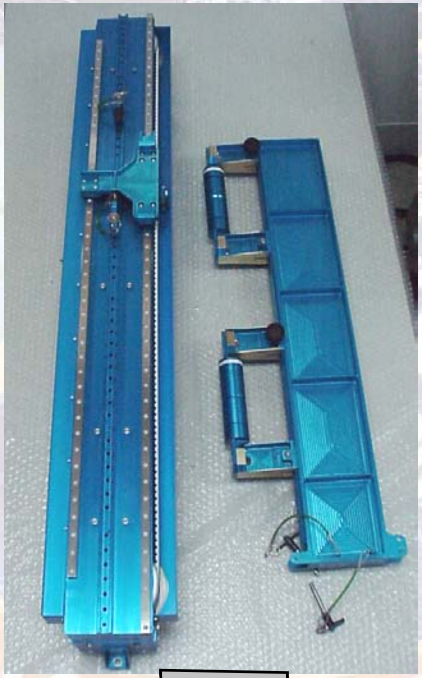




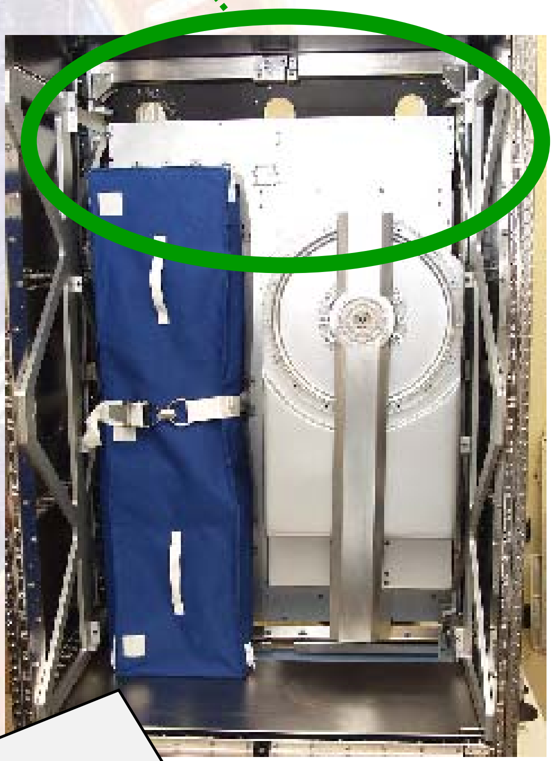
MARES Rack Stowage (continued)

- **On-orbit configuration**
  - **MARES on-orbit stowage locations will consist of:**
    - **1 MARES on-orbit stowage bag**
    - **1 Linear Adapter stowage bag**
    - **1 HRF MARES Rack stowage drawer**
  - **The MARES on-orbit stowage bag will contain the items from the M02 bag that need to be stowed prior to use in an experiment:**
    - **MARES levers (long/medium/short)**
    - **MARES trunk adapter**
    - **MARES ankle restraint**
    - **MARES handgrip adapter**
    - **MARES adjustable structure(s)**
    - **Miscellaneous other pieces**
  - **The Linear Adapter and MARES rack stowage drawer locations are nearly identical to their launch configurations.**





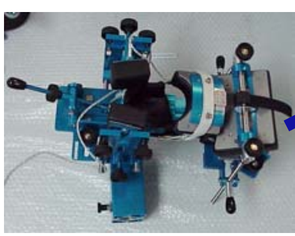
Additional area observed during recent HFE evaluation that could be utilized for additional on-orbit stowage

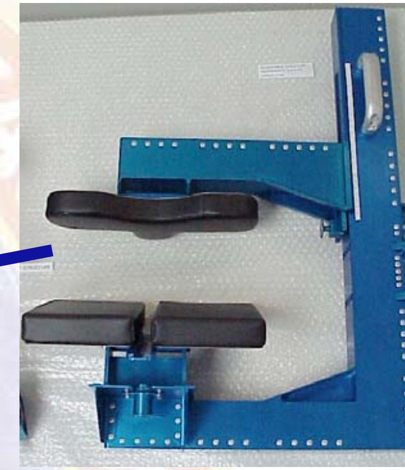


HRF MARES Rack
System Design Review

Human Research Facility (HRF) Project

12/16/2003

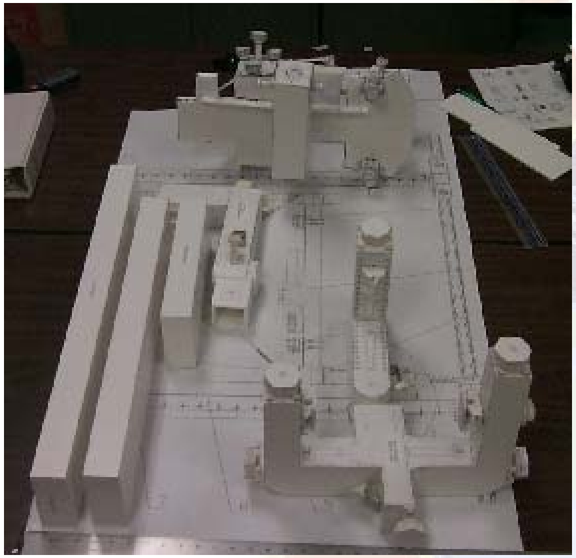




Other parts…

MARES Rack Stowage (continued)

- **Prototype Evaluations**
  - **Mockups, fabricated to available MARES drawings, were used to determine arrangements for launch and on-orbit stowage**
  - **Once stowage arrangements were created, Nomex pouches and foam cushions were developed to simulate the stowage containers**
  - **The prototype stowage containers are expected to be taken to ESA to verify sizes, interferences, quantities and protrusions with the existing hardware early in CY ‘04**



Human Factors Engineering

Cynthia Hudy
Danielle Paige

Human Factors Evaluations

- **Individual Human Factors evaluations were performed on the MARES Rack structure, Power Interface Panel (PIP), and drawings of the Vibration Isolation Frame (VIF), Launch Stowage Plate (L/SP), and Launch Support Adapter (LSA)**
  - Examined the usability of the individual hardware items
  - Reviewed compliance with SSP 57000 HFE requirements

- **In addition, HFE performed a usability evaluation of the MARES from launch configuration to on-orbit stowed configuration**

SSP 57000 HFE Requirements

MARES Rack Structure –

- **No SSP 57000 requirements issues anticipated**
  - Similar to other HRF Racks
  - Struts are joined by tethered pins
  - Labeling:
    - Rack name label – will use new “combo” label
      - Title case, barcode on right
    - Inside of right and left seat track individually labeled with 1-63
      - Will promote ease of alignment/ location for VIF
    - Discussed with ISS Payload Label Approval Team (IPLAT) and received verbal approval for label concept

SSP 57000 HFE Requirements

VIF, L/SP, & LSA

- **Drawings have been reviewed to assess:**
  - Seat track interfaces
  - Visual accessibility of bolts/pins
  - Labeling:
    - Name and IMS label for each piece; use “combo” labels

- **SSP 57000 requirements issues anticipated**
  - Mounting Bolt/Fastener Spacing
    - Clearance around L/SP bolts does not meet tool handle sweep requirements
  - Handles and Restraints
    - L/SP must be provided with a suitable means of grasping
    - MARES Team is working on a solution

SSP 57000 HFE Requirements

Power Interface Panel (PIP)

- **Preliminary hardware evaluations included:**
  - Strength requirements
  - Clearance and Accessibility
  - Connector arrangement and protection
  - Switch placement and protection
  - Labeling:
    - “Power Out” interfaces are grouped
    - Connectors on bottom are labeled on both sides for visibility
    - Safety switch uses ISS RMS decal
    - Discussed with IPLAT and received verbal approval for label concept

SSP 57000 HFE Requirements

Power Interface Panel (PIP)

- **SSP 57000 requirements issues anticipated**
  - Handle Dimensions
    - Handle height does not meet requirements
  - Alignment and Torque for seat track interface with MARES Rack
    - Attaching PIP to Rack is difficult
    - MARES Team is working on a solution

MARES Launch and On-orbit Stowage Usability

- **Human factors personnel performed an informal usability review of the MARES stowage concepts**
  - Payload Office Human Factors Implementation Team (HFIT) members present for waiver pre-planning; crew were not able to attend

- **Current launch and stowage concepts are well thought-out. Procedure development was very helpful in addressing system-component operations and interactions**

- **Human factors requirements were implemented where feasible and team is still working on improving system interfaces for increased usability**

MARES Launch and On-orbit Stowage Usability

- **Issues to be addressed:**
  - **Temp stow**
    - Issue: Too much equipment to be temp stowed during configuration changes
    - Solution: Necessary to have Payload Equipment Restraint System (PERS), stowage net, or additional stowage bag
  - **Restraints**
    - Issue: Handrails and foot restraints will be necessary for deployment from launch configuration
    - Solution: Foot restraints (LDFR, SDFR) can be deployed on adjacent racks
  - **Handles**
    - Issue: Handles are needed on MARES equipment for easier grasping and maneuvering
    - Solution: There is room on L/SP to add handles

MARES Launch and On-orbit Stowage Usability

- **Issues to be addressed:**
  - **Lighting**
    - Issue: Many operations will be performed inside the rack
    - Solution: Additional light, such as the Payload Utility Light (PUL), can be attached to handrails
  - **Two-person Operation**
    - Solution: Crew procedures and timeline will reflect need for more than one crew for assembly
  - **Accessibility & Reach**
    - Issue: Reach inside the rack may be difficult (30” reach from rack face to LSP in on-orbit stowage configuration)
    - Solution: Handles inside rack
  - **Tool sweep**
    - Issue: Bolts on LSP do not provide enough clearance for tools
    - Solution: Tool extenders will be used from the on-orbit tool kit

MARES Launch and On-orbit Stowage Usability

- **Issues to be addressed:**
  - **Strength for bolt torque/ repetition**
    - Issue: Bolt torque may be too difficult, especially given the number of bolts
    - Solution: Use electronic tools in on-orbit tool kit
  - **Screw and bolt protrusion**
    - Issue: Temporarily protruding pins and screw threads need to be covered or capped
    - Solution: Foam blocks can be made to cover protruding ends
  - **Blind mate connectors**
    - Issue: Alignment of pins on rear panel of MARES Main Box is difficult
    - Solution: Add alignment marks on L/SP to assist in placement of Main Box

Conclusions & Forward Work

- **Human factors personnel will continue to work with MARES Rack team on human factors issues**
  - Continue to work with Engineering personnel to improve usability
  - Continue to work with Stowage team to ensure adequate placement of items for accessibility
  - Continue to work with Procedures and OpNom for appropriateness of hardware names and IPLAT for labeling evaluations

- **Currently, MARES Rack and PIP hardware meets most SSP 57000, Rev. E human factors requirements**
  - Future work will include HFIT and the crew office to approve waivers

- **MARES team has done an excellent job in including and considering human factors**

Structural Analysis

Structural Analysis Outline

- Structural Verification Plans
- FEM Description
- Launch Configuration Control Mass Properties
- Dynamic Analysis
- MARES Experiment Hardware Structural Assessment
- ISPR Generic Design Loads and Structural Assessment
- Integration Hardware Generic Design Loads
- Integration Hardware Structural Assessments
- ISPR and Integration Hardware Forward Work

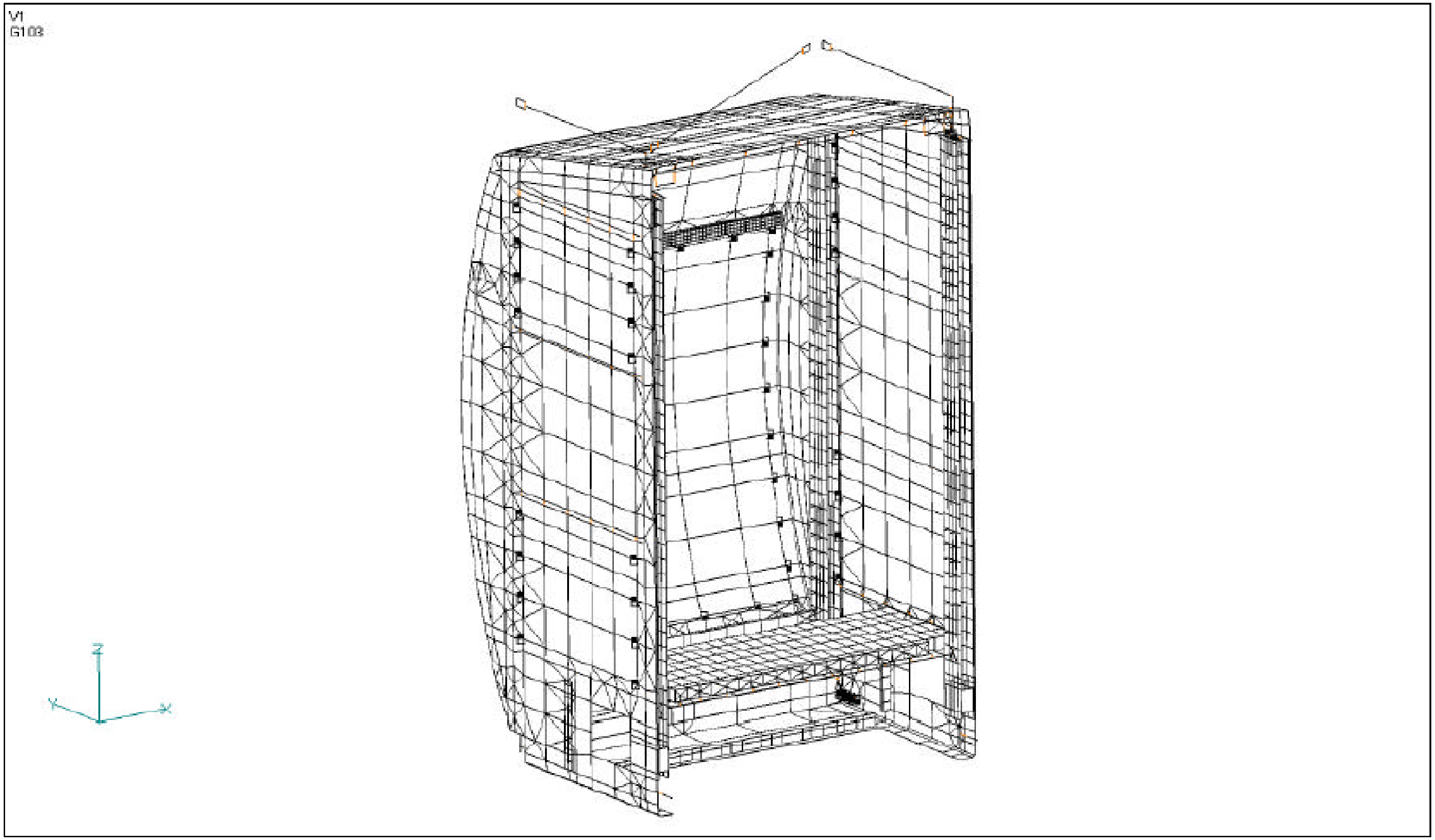
Structural Verification Plans

- HRF MARES Rack and Payload Equipment, LMSEAT 34144
  - Provides comprehensive plan for the integrated rack
  - Defines organizations involved and associated products
  - Details the analysis methods for the integration hardware
  - References SSP57007 as the established guideline for analysis of ISPR structure
  - Available in draft form – requires additional information for the soft stowage bags system
- MARES Structural Verification Plan, MARES-0000-PL-177-NTE
  - Details the analysis methods for the MARES experiment hardware
  - Available in draft form – text is final, only requires final signatures

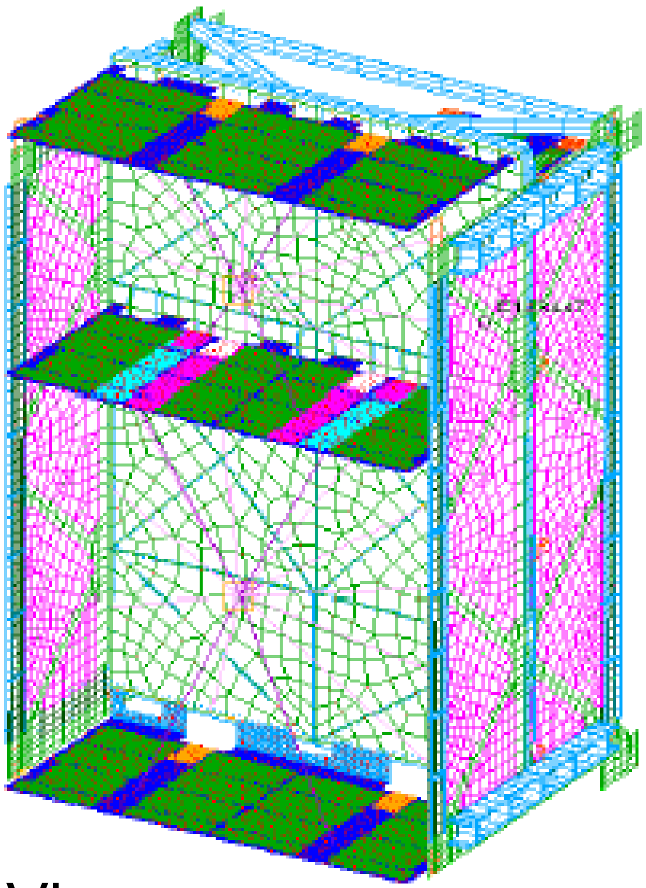
FEM Description

- HRF MARES Rack Finite Element Models (FEM) were developed by three companies (NTE, Boeing, and Lockheed Martin)
- NTE developed the MARES experiment hardware FEM
- Boeing developed the modified 4-post ISPR FEM (static and dynamic versions). Modification include:
  - Upper intercostal was replaced with a recessed version that allows for additional stowage space
  - Standard Vertical Utility Panel was removed
- Lockheed Martin developed the integration hardware FEM, required to launch the MARES experiment hardware in the ISPR. Integration hardware includes:
  - Launch Support Adaptor (LSA)
  - Launch Stowage Plate (L/SP)
  - Right and Left L/SP Support Structures
  - Stowage Bag Systems (MO1, MO2, and Linear Adapter Bag)
  - MARES Rack Stowage Drawer & modified Vertical Utility Panel

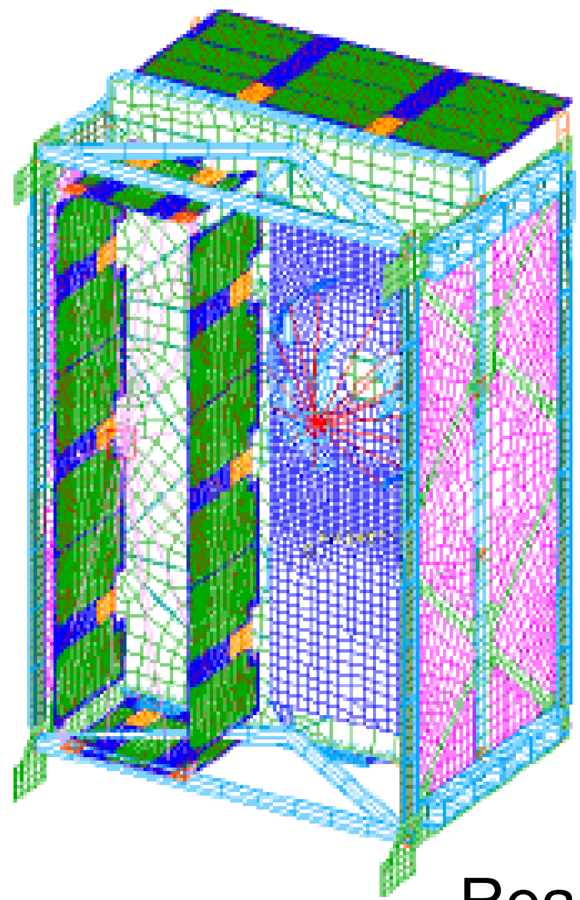
Modified 4-Post ISPR Dynamic Model



Integration Hardware FEM

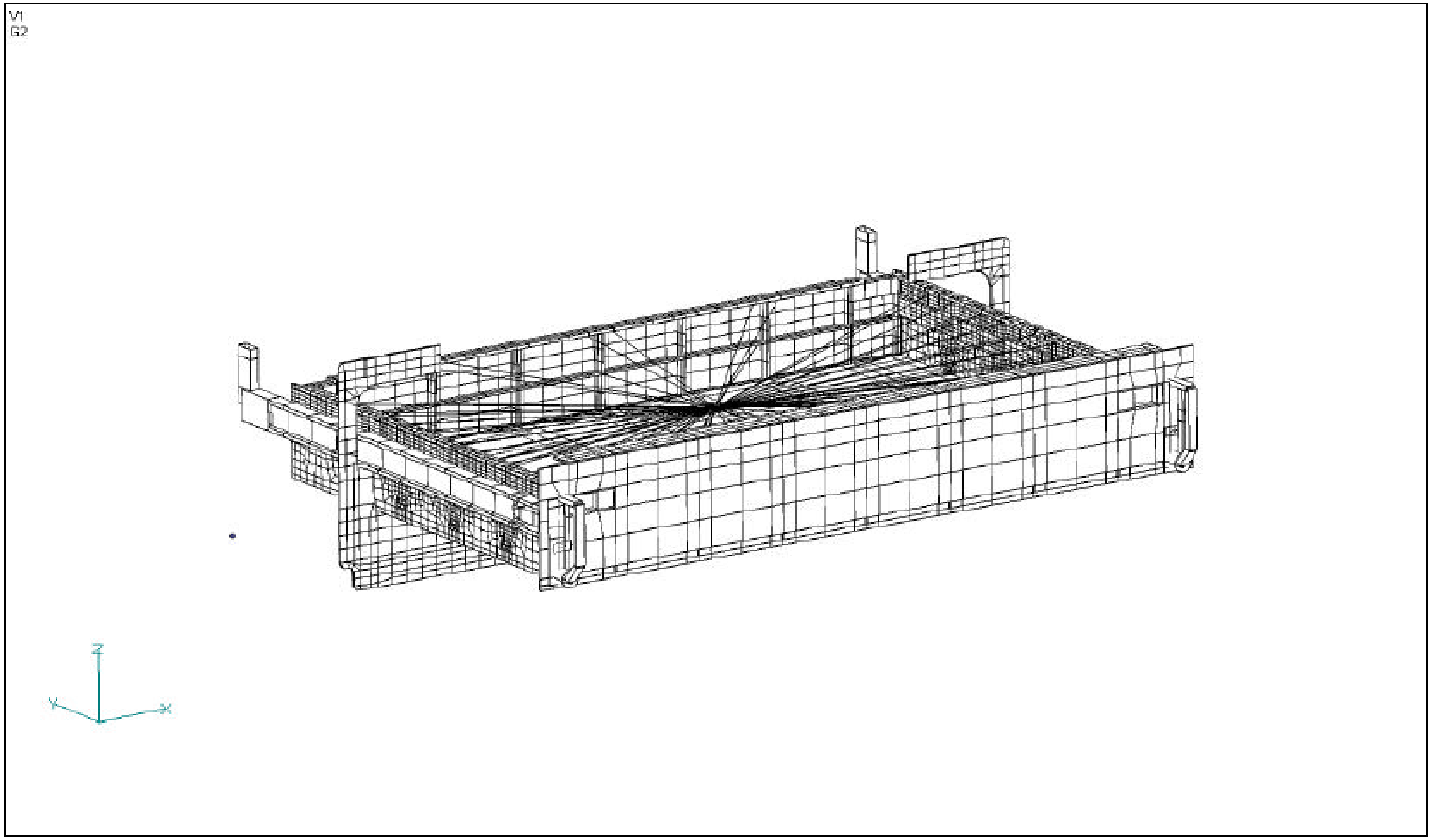


Front View

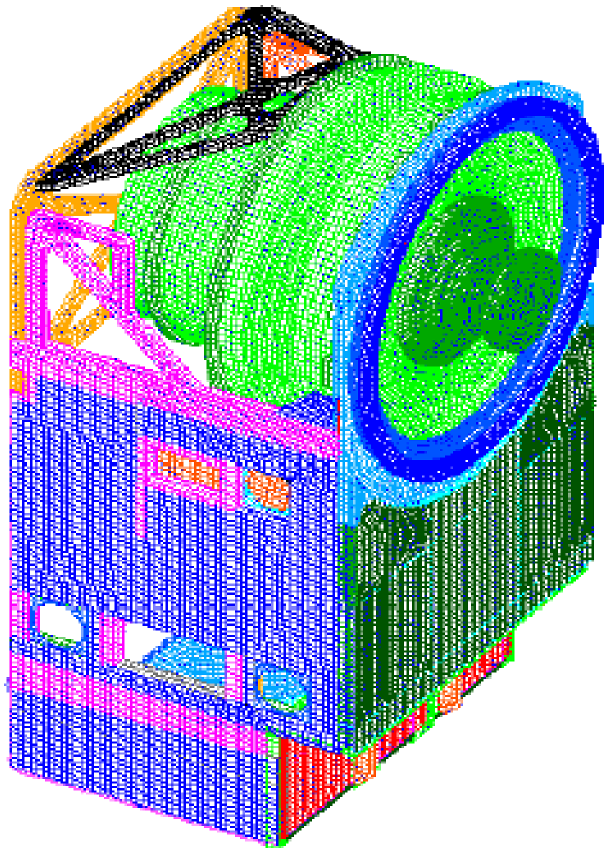


Rear View

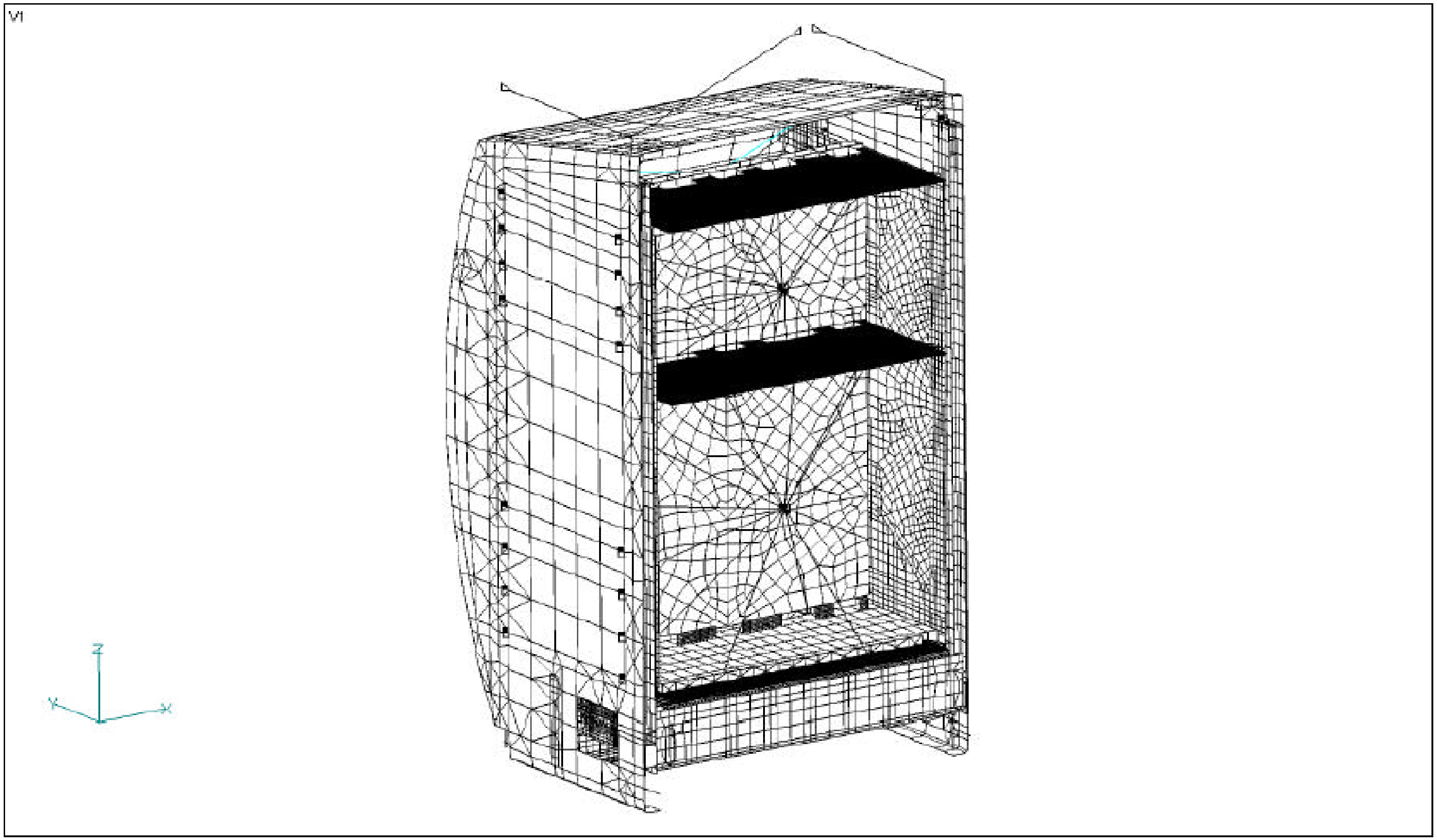
Integration Hardware FEM



MARES Main Box FEM



Integrated Rack FEM



Launch Configuration Control Mass Properties

HRF MARES Rack Launch Configuration Mass Properties				
Hardware	**Est. Mass (lbs)**	**Control Mass (lbs)**	**Uncertainty Factor**	**Dynamic FEM (lbs)**
Basic Rack	250.00	250.00		203.87
Knee Brace	11.94	11.94	0%	10.31
MARES Main Box	236.34	242.51	3%	244.33
LSA	50.00	55.00	10%	55.37
LSP	80.00	88.00	10%	90.65
LSP Support Structure	95.05	104.56	10%	106
MO1 Bag System	31.88	36.66	15%	24.82
MO1 Bag Contents	199.36	239.24	20%	251.06
MO2 Bag System	22.01	25.31	15%	10.82
MO2 Bag Contents	79.32	95.18	20%	113.56
VIF Launch Bag System	46.80	53.82	15%	28.75
VIF Launch Bag Contents	48.07	57.69	20%	83.25
Stowage Drawer Structure	30.60	33.66	10%	33.66
Stowage Drawer Contents	21.64	50.00	20%	50.00
Slide Guide Asemblies	4.32	4.75	10%	4.75
Utility Panel	2.54	2.79	10%	2.69
TOTAL	**1209.9**	**1351.1**		**1313.9**

Integrated Rack Dynamic Analysis

- The dynamic HRF integrated MARES Rack FEM was developed by combining:
  - The modified 4-post ISPR dynamic FEM
  - The integration hardware FEM
  - Con Mass elements that represent the Mass Properties of the MARES Main Box and stowage bags
- The dynamic FEM was constrained at the MPLM attachment interface and a normal mode analysis was performed
- The first mode is 25.00 Hz translating in the X-direction with 94.5% of the total rack mass participation (SSP57000, 3.1.1.4-C, and SSP 52005, 5.7, require a minimum natural frequency of 25 Hz)
- The system mode frequencies are 25.00 Hz, 33.56 Hz, and 51.17 Hz for X, Y, and Z-directions, respectively

Integrated Rack Dynamic Analysis (cont.)

Natural Frequencies and Model Effective Mass Ratios (MEMR) predicted by MARES Math Model

MODE	RESONANT FREQUENCY (HZ)		MEM Ratios in % of Total By Analysis — MARES DYNAMIC MODEL						REMARKS
	Test	Math Model	TX	TY	TZ	RX	RY	RZ	
1		25.00	94.5%	0.3%	0.0%	0.0%	0.0%	1.4%	Math Model = MARES_DYN_02A.MOD
2		33.56	0.0%	15.4%	0.1%	11.2%	0.0%	0.0%	Total Mass = 1314 lbm
3		38.53	0.2%	38.8%	8.3%	1.1%	0.0%	0.0%	
4		40.16	0.0%	0.0%	0.0%	0.0%	0.2%	0.5%	
5		41.66	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	
6		45.21	0.0%	19.9%	5.2%	17.9%	2.9%	1.2%	
7		49.67	0.2%	2.0%	1.1%	0.4%	31.8%	9.4%	
8		51.17	0.0%	0.2%	15.5%	1.5%	0.2%	0.4%	
9		58.87	0.0%	0.2%	0.0%	0.2%	0.0%	0.1%	
10		59.03	0.2%	1.2%	13.9%	6.6%	0.0%	22.2%	
11									
12									
	TOTAL (%)		95.2%	77.9%	45.0%	39.0%	35.1%	35.3%	

Integration Hardware Dynamic Analysis

- **The LSA, L/SP, L/SP Support Structure and stowage bag systems FEM were combined with con mass elements that represent the MARES Main Box and stowage bags**
  - **The combined FEM was constrained at the rack attachment interface and a normal mode analysis was performed**
  - **The first mode is 42.27 Hz translating in the Z-direction with 8.35% of the payload mass participation. (SSP57000, 3.1.1.4-D, and SSP 52005, 5.7, require a minimum natural frequency of 35 Hz)**
  - **The system mode frequencies are 78.65 Hz, 53.84 Hz, and 42.27 Hz for X, Y, and Z-directions, respectively**

Integration Hardware Dynamic Analysis (cont.)

- The stowage drawer FEM was constrained at the rack attachment interface and a normal mode analysis was performed
  - The first mode is 54.05 Hz translating in the Y-direction with 63.1 % of the payload mass participation. (SSP57000, 3.1.1.4-D, and SSP 52005, 5.7, require a minimum natural frequency of 35 Hz)
  - The system mode frequencies are 56.28 Hz, 60.21 Hz, and 54.05 Hz for X, Y, and Z-directions, respectively

MARES Experiment Hardware Structural Assessments

- MARES experiment hardware is being analyzed by NTE in accordance to the MARES Structural Verification Plan, MARES-0000-PL-177-NTE.

ISPR Generic Design Loads and Structural Assessment

- Acceleration environment (defined by SSP41017) was applied to the integrated rack FEM for analysis of the ISPR structure

	Nx(g)	Ny(g)	Nz(g)	Rx * (rad/sec^2)	Ry* (rad/sec^2)	Rz* (rad/sec^2)
Launch	+/–7.0	+/–8.0	+/–7.8	+/–70.8	+/–21.7	+/–34.8
Landing	+/–5.3	+/–7.2	+/–9.0	+/–37.1	+/–23.0	+/–28.3

- ISPR structure is being analyzed by Boeing in accordance to the material strengths, failure modes, and analysis requirements defined by SSP57007 and SSP41017
- Current assessments include launch/landing analysis for primary structures of the ISPR
- Design changes to increase the rack stiffness were not represented in the ISPR analysis, but are expected to improve ISPR loading
- Assessment revealed a need for ISPR post reinforcement clips

ISPR Minimum Margin of Safety Summary

ISPR Component	Analysis ECD	Margin of Safety (ult)	Margin of Safety (yld)	Failure Mode
Forward and Aft Posts	Completed	+ 0.01	n/a	Aft Post Flange Surface Strain
Pivot Fittings	Completed	+ 1.22	n/a	Bolt Shear Tension Interaction
Utility Panel Assembly	Completed	+ 0.27	+ 0.55	Shear Bearing in Support Panel
Upper Attach Fittings	Completed	+ 0.20	+ 0.91	Shear Bearing in Composite Skin
Horizontal Beam & Beam Attach Fitting	Completed	+ 0.30	n/a	Bolt Shear Tension Interaction

ISPR Minimum Margin of Safety Summary (cont.)

ISPR Component	Analysis ECD	Margin of Safety (ult)	Margin of Safety (yld)	Failure Mode
Rear Access Panel	Completed	+ 0.09	+ 0.53	Buckling
Skin and Side Access Panels	Completed	+ 0.02	+ 0.61	Shear Bearing in Composite Panel
Intercostals	Completed	- 0.30*	n/a	Bearing in Intercostal
Attach Pins	Completed	+ 0.05	+ 0.30	Pin Bending
Lower Rear Horizontal Member	Completed	+ 0.68	+ 1.66	Shear Bearing in Composite Skin
Lower Right Attach Fitting and Clip	Completed	+ 0.01	n/a	Shear Out in Z-Flange

ISPR Minimum Margin of Safety Summary (cont.)

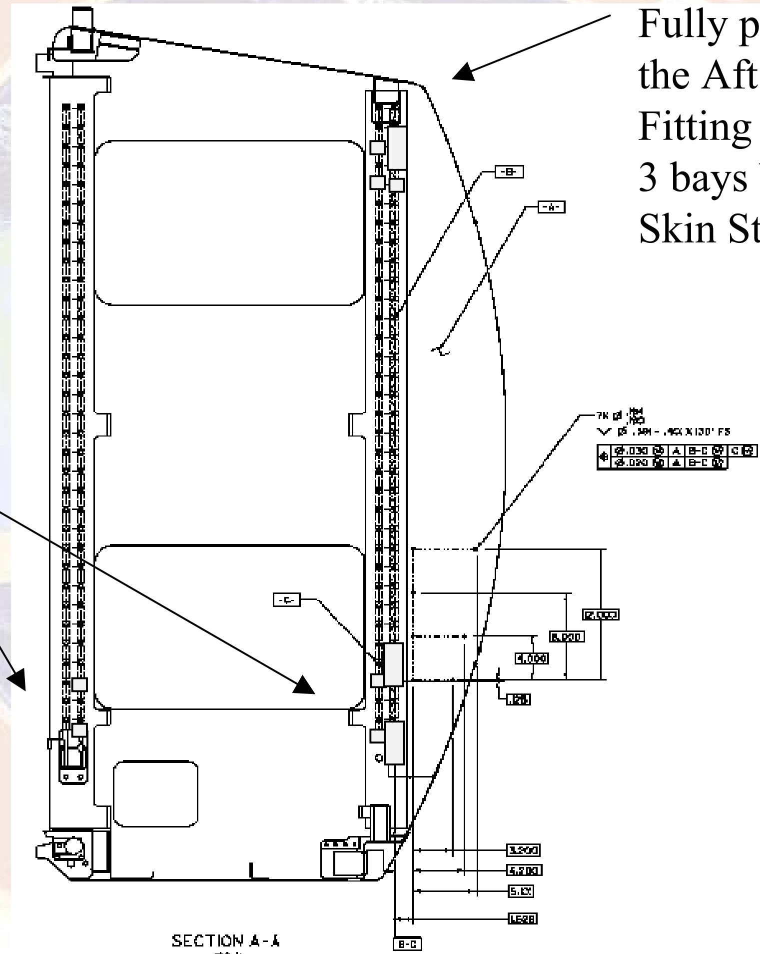
ISPR Component	Analysis ECD	Margin of Safety (ult)	Margin of Safety (yld)	Failure Mode
Lower Left Attach Fitting and Clip	Completed	+0.24	+0.59	Net Section
Rack Insertion Analysis	12-5-2003	TBD	TBD	TBD
Upper Torque Tubes & Torque Tube Clips	Completed	-0.11*	-0.16*	Plate Bending
Skin Stabilizers	12-19-2003	TBD	TBD	TBD

* Less conservative analytical techniques are being investigated to relieve negative margins of safety.

Analysis has not gone through Boeing internal checks and should be considered preliminary. A full rack report will be issued approximately 30 days after the completion of the stress analysis.

ISPR Post Reinforcement Clip Locations

- Fully populate the Forward Post Aft cavity and both cavities of the Aft Post from the Lower Fittings to a minimum height of one clip bay above the Lower Side Skin Stabilizer.



Fully populate both cavities of the Aft Post from the Upper Fitting to a minimum depth of 3 bays beneath the Upper Side Skin Stabilizer

Note:

The left side clip locations mirror the right side clip locations.

Integration Hardware Generic Design Loads

- **Analysis loads for both the integration hardware and stowage drawer were generated by combining quasi-static and random vibration loads per SSP52005B.**
- **Quasi-static load factors are obtained from the SSP 57000E.**

Liftoff	X	Y	Z
(g)	± 7.7	± 11.6	± 9.9
Landing	X	Y	Z
(g)	± 5.4	± 7.7	± 8.8
Note: Load factors apply concurrently in all possible combinations for each event and are shown in the rack coordinate system defined in SSP 41017, Part 2, paragraph 3.1.3.			

Integration Hardware Generic Design Loads (cont.)

- **Random Vibration Environment is obtained from SSP 57000E. Random vibration load factors are generated using Mile's equation in conjunction with the modal mass participation method per SSP52005B**
  - **Random Vibration Environment for LSA, L/SP, L/SP Support Structure**

FREQUENCY	LEVEL
20 Hz	0.002 g^2/Hz
20–70 Hz	+ 4.8 dB/oct
70–150 Hz	0.015 g^2/Hz
150–2000 Hz	–3.7 dB/oct
2000 Hz	0.0006 g^2/Hz
Composite	2.4 grms
Note: Criteria is the same for all directions (X,Y,Z)	

Integration Hardware Generic Design Loads (cont.)

- Random Vibration Environment for Stowage Drawer

FREQUENCY	LEVEL
20 Hz	0.005 g^2/Hz
20–70 Hz	+ 5.0 dB/oct
70–200 Hz	0.04 g^2/Hz
200–2000 Hz	–3.9 dB/oct
2000 Hz	0.002 g^2/Hz
Composite	4.4 grms
Note: Criteria is the same for all directions (X,Y,Z)	

Integration Hardware Structural Assessments

- Integration hardware is being analyzed by Lockheed Martin in accordance to the material strengths, failure modes, and analysis requirements defined by SSP52005 and the Structural Verifications Plan for the Human Research Facility's (HRF) Muscle Atrophy Research and Exercise System (MARES) Rack and Payload Equipment, LMSEAT-34144
- Current assessments include launch/landing analysis (yield, ultimate, joint separation, fastener bearing, and fastener tear out) for LSA, L/SP, Right and Left L/SP Support Structure, and Stowage Drawer assemblies

LSA, L/SP, Right and Left L/SP Support Structure Minimum Margin of Safety Summary

Item Description	Material	Failure Mode	Factor of Safety	Minimum Margin of Safety
LSA	Al 7075-T7351	Bending, Ultimate	2.00	0.82
L/SP	Al 7075-T7351	Bending, Ultimate	2.00	0.00
Right and Left L/SP Support Structure	Al 7075-T7351	Bending, Ultimate	2.00	6.46
Fasteners (Only MARES to LSA and LSA to L/SP bolts have been analyzed.)	CRES A-286	Combined Shear and tension, yield	1.25	0.02
Struts	Al 6061-T6	Combined Axial and Bending, Ultimate	2.00	2.68

Analysis results are preliminary.

MARES Rack Stowage Drawer
Minimum Margin of Safety Summary

Item Description	Material	Failure Mode	Yield Strength		Ultimate Strength	
			Factor of Safety	Minimum Margin of Safety	Factor of Safety	Minimum Margin of Safety
Slide Guide	7075-T7351 AL ALY	Combined	1.25	0.59	2.0	0.19
Slide	7075-T7351 AL ALY	Combined	1.25	1.67	2.0	1.12
Front Panel	7075-T7351 AL ALY	Combined	1.25	1.96	2.0	1.07
Rear Panel	7075-T7351 AL ALY	Combined	1.25	2.11	2.0	1.27
Side Panels	7075-T7351 AL ALY	Combined	1.25	0.59	2.0	0.05
Bottom Panel	7075-T7351 AL ALY	Combined	1.25	4.50	2.0	3.00
Fasteners	A286	Combined	1.25	0.13	2.0	0.34
Latch Pins	CRES 300	Combined	1.25	0.29	2.0	0.48

Analysis results are preliminary.

ISPR and Integration Hardware Forward Work

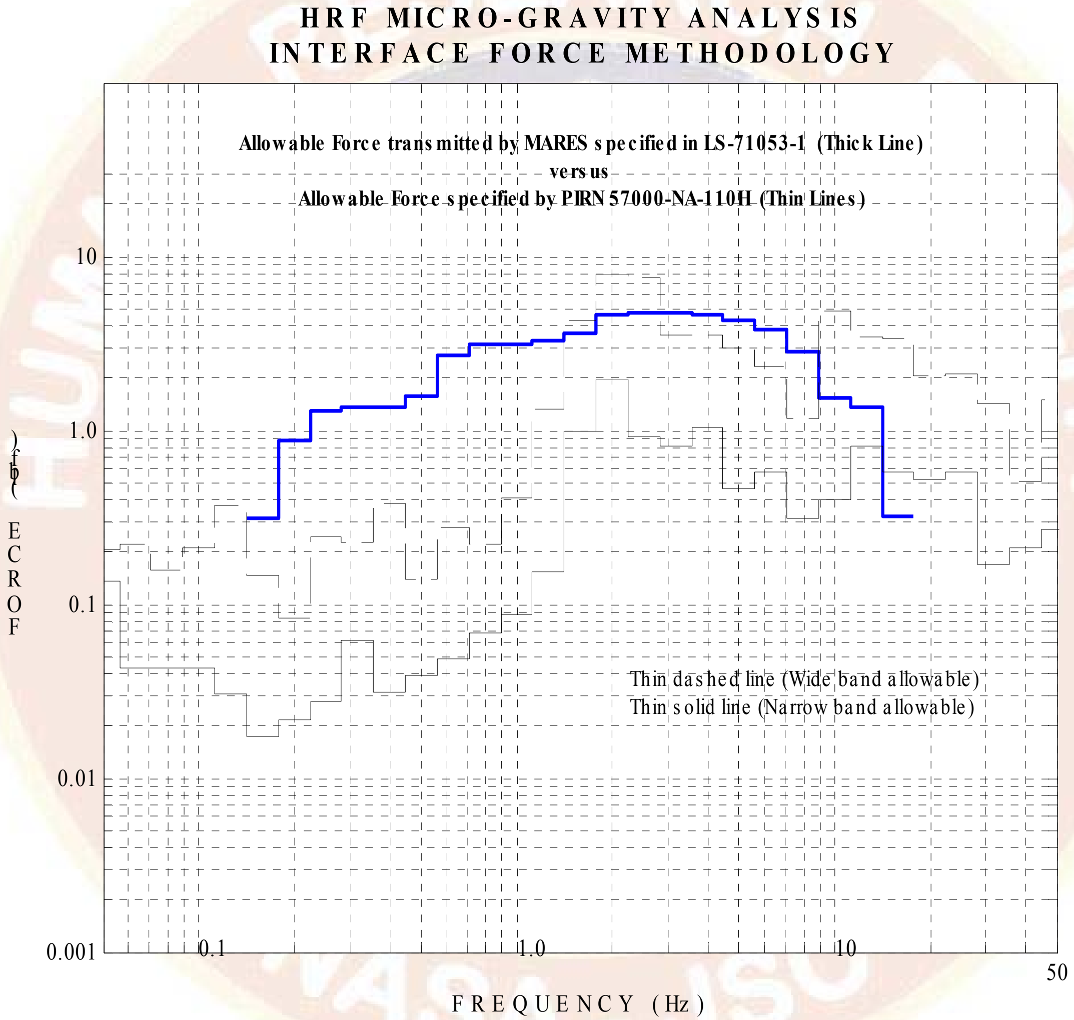
Open Work	Completion Date
Baseline HRF MARES Rack and Payload Equipment SVP, LMSEAT 34144	December 31, 2003
Launch/Landing loads analysis for Stowage Bag System	March 10, 2004
Buckling and Crippling Analysis	March 10, 2004
Fail-safe Analysis	March 10, 2004
Fatigue Analysis	March 10, 2004
Fracture Control Assessment	March 10, 2004
Rack–induced Loads Analysis	January 22, 2004

ISPR and Integration Hardware Forward Work

Open Work	Completion Date
Containment analysis for Stowage Drawer cover straps/webbing	December 31, 2003
Repress/Depress Analysis for Power Interface Panel (PIP)	March 10, 2004
On-orbit loads analysis	February 11, 2004
Crew-induced Loads Analysis	March 10, 2004
Modal Survey of MARES Rack	July 13, 2004

Microgravity Analysis

- ISPR and Integration hardware do not generate microgravity disturbances
- Operational disturbances produced by the MARES Mainbox and ancillary hardware will be characterized by NTE in accordance to MARES-1900-PL-181-NTE
  - Analysis will be performed using the methodology defined in PIRN-57000-0110H
  - Disturbance will be compared with allowable levels defined in the MARES HRD, LS-71053-1
- The MARES Vibration Isolation Frame (VIF) was designed to reduce disturbances to station
- LM will process NTE analysis results to characterize disturbance at the Rack to Lab interface or at an adjacent ARIS interface and provide a comparison to allowable levels defined by PIRN-57000-0110H



HRF MICRO-GRAVITY ANALYSIS
INTERFACE FORCE METHODOLOGY
Allowable Force transmitted by MARES specified in LS-71053-1 (Thick Line)
versus
Allowable Force specified by PIRN 57000-NA-110H (Thin Lines)
10
1.0
0.1
0.01
0.001
FORCE (lbf)
Thin dashed line (Wide band allowable)
Thin solid line (Narrow band allowable)
0.1
1.0
10
50
FREQUENCY (Hz)

PIP Thermal Analysis

Thermal Interface Requirements

- Touch temperature design requirements per LS-71090-1 Sect. 3.3.6.9 (SSP 57000E Sect. 3.12.3.2.1)
  - Continuous/Incidental contact high temp. (touch) limit of 120°F (49°C)
  - Normal on-orbit internal operating environments are defined as temperatures in the range of 63 to 82°F (17 to 28°C) and pressures in the range of 13.9 to 14.9 PSIA

- EXPRESS Rack Payloads IDD (SSP 52000-IDD ERP)
  - The mean radiant environment for the cabin is 65 - 86 F
  - The convective heat transfer coefficient from the payload enclosure to the cabin is 0.2 BTU/hr F ft^2 at 14.7 psia

Thermal Design

- PIP unit was analyzed for 6 amp load (33 Watts of heat dissipation)
- Switch and Control Boards are attached to the structure via aluminum heat sinks and thermal interface pads
- External walls are cooled via radiation and convection to cabin air and walls
- Upper and lower PIP walls are finned to enhance cooling
- External aluminum surfaces are blue anodized with an emittance of 0.85

Thermal Model

- The model considers conduction, convection, and radiation heat transfer modes
- TSS was used for the geometry model, and SINDA was used for the thermal network model
- The unit was analyzed for nominal operations under 14.7 psia pressure conditions
- Control and Filter Boards were modeled as single nodes, with the total heat dissipation for each applied uniformly to that node
- Switch board was modeled as 20 nodes
- Heat balances were performed as a system check of the thermal model
- Cabin air temperature assumed to be 82 °F (28.0 °C)
- Mean radiant environment assumed to be 86 °F (30 °C)

Hardware Heat Dissipation

- Heat dissipation based on a 6 amp load

ITEM	Heat Dissipation (W)
Switch Board	13.7
Control Board	17.3
Filter Board	2.0
Total	**33.0**

Analysis Results

- Results for worst-case environment conditions and 6 amp load

ITEM	Max. Operating Temperature	Steady State Results
Outer Walls	**120 F (49 C)**	**119 F (48 C) max.**
Switch Board	**212 F (100C)****	**161 F (72 C) max.**
Switch Board (near diodes 1&2)		161 F (72 C)
Switch Board (Avg.)		128 F (58 C)
Heat Sink (Avg.)		119 F (48 C)
Heat Sink (Near Thermal Switch)		124 F (51 C)
Control Board*	**158 F (70C)****	**123 F (51 C)**
Heat Sink		120 F (49 C)
Filter Board*	**185 F (85 C)****	**126 F (52 C)**

- *Control and Filter Boards are modeled as single nodes.
- **Lowest maximum component temperature limit for that board.

- External wall temperature of 119°F (touch temperature limit 120°F)

Science and Operations

Science and Operations

- **MARES/MARES Rack Hardware Document**
  - Operational details of the MARES in all joint configurations
  - Initial deployment
  - Functional test
- **Draft Manifest**
  - Working version used for stowage, verification, op nom, etc
  - Ascent
  - Decent – Temp stow plan plate, fences, M01, M02
- **Operation Nomenclature**
  - Prepared from manifest
  - Submitted to MSFC following SDR
- **Initial Deployment Procedures are Posted in the Data Pack**

Initial Deployment

- Transfer from MPLM to Columbus module

- Straps released, M01, M02 bags removed
- Fences removed
- LSP rotated to expose Main Box, Linear Adapter Bag
- Electronics installed in Main Box
- VIF deployed, Main Box/LSA removed from LSP and placed on VIF
- Main Box removed from LSA
- Pantograph, chair and other attachments installed on Main Box
- Additional configuring for test or stowage
- Battery charging required before first use
- M02 foam and contents transferred to On-Orbit Stowage Bag
- M01 Bag with foam, M02 Bag and all fences to be returned

Science and Operations: Functional Checkout

- Power test standalone: systems active, battery charged, etc.
- Subsystems test: self test level.
- Motion test w/o subject: tests motor, electronics units, sensors, end-stops, SCSI drives, s/w, etc.
- Test data downlink through HRF Workstation.
- Test data communication with PEMS-2.
- Test EMG interface with ADAS.
- Calibration.
- Experiment software set-up and check.
- Data analysis on ground.
- Human Restraint System inspection, fit-check and stowage.
- VIF inspection. VIF test with video downlink.
- Set-up stowage configuration.

Science and Operations

- **Procedures and Training**
  - Draft version of procedures posted. Further details added when hardware available
  - Draft training plans in HD. To be updated when hardware available
  - Procedures submitted for baselining at I-18
  - Training plans submitted at I-15. Training to start at I-12
  - Stowage training with foam mockups to take place in Bldg. 9. Protocol training to take place in Bldg 241 or 36

Safety

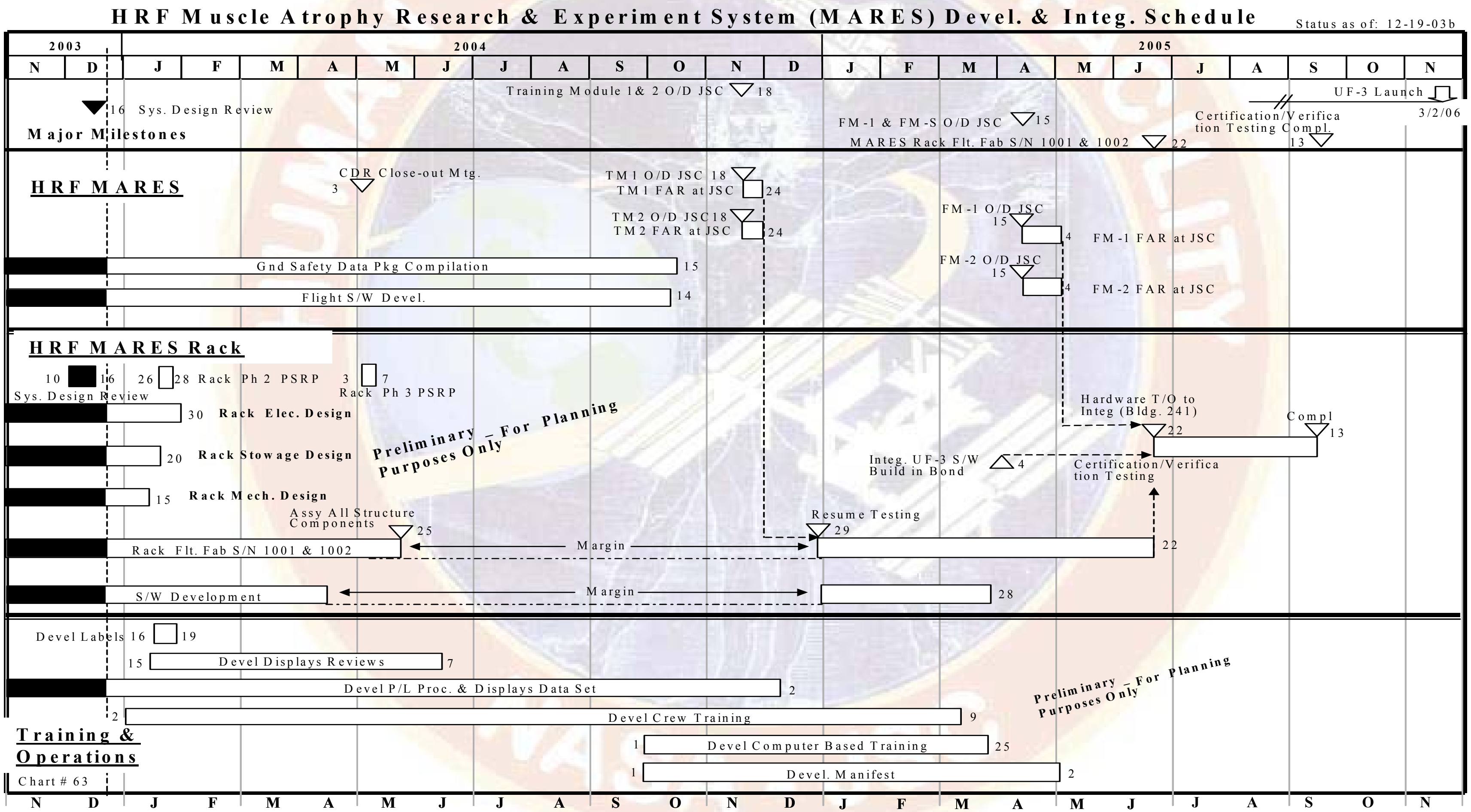
- Phase I PSRP Status - completed
- Phase II PSRP Status – Package ready for submittal
- Hazards – Standard hazards (sharp edges, materials, EMI, touch temp, power distribution) along with a Unique Hazard Report covering controls and verifications for Structural Failure
- Forward Work
  - Complete Phase II review February 04
  - Phase III review will be an integrated review with MARES and the MARES rack

Reliability

- IAC- The HRF MARES Rack is Functional Criticality 3 hardware as defined in the posted Initial Assessment of Criticality

- R&M Prediction Report – In work

Development Schedule



Conclusions

- Hardware Engineering will continue to work with Human Factors, Science, Operations, and MARES development personnel to improve the usability of the system within the confines of the design requirements
- The design meets the requirements of the System Requirements Document with identified exceptions
- Hardware Engineering is prepared to proceed with the Flight Production and Certification Life Cycle Phase